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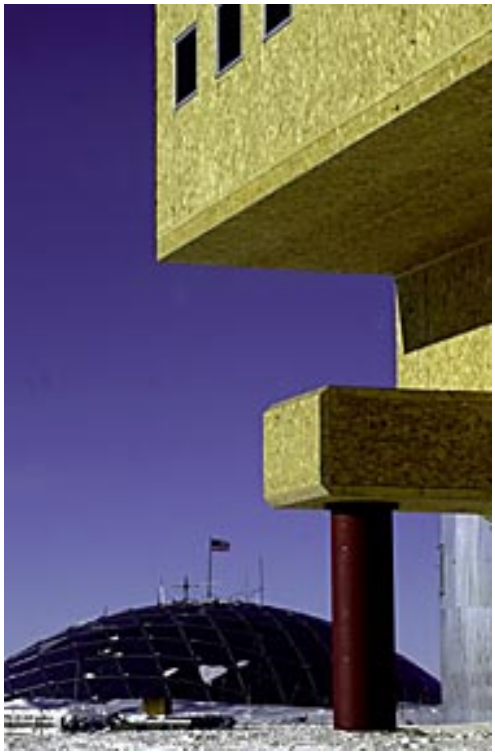

The first phase of the new Amundsen-Scott South Pole Station (foreground) as it appeared in November 2001. This first wing houses 50 people and the dining facility. In the background is the geodesic dome that houses most of the current station buildings. *(NSF/USAP photo by Melanie Conner)*

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U.S. ANTARTIC PROGRAM, 2002-2003

The U.S. flag flies at the American research station Palmer in the Antarctic Peninsula. *(NSF/USAP photo by David Bresnahan)*

As part of the U.S. Antarctic Program, nearly 700 researchers and special participants will conduct 141 projects during the 2002–2003 austral summer, with some projects continuing through the austral winter. Supported by over 2,000 civilian contract employees and U.S. military personnel, these researchers and such special participants as writers, artists, and teachers will work at the three U.S. year-round stations (McMurdo, Amundsen–Scott South Pole, and Palmer), at remote field camps, with other national antarctic programs at locations around Antarctica, and in the waters of the Southern Ocean aboard the U.S. Antarctic Program's two research ships—the icebreaking research ship *Nathaniel B. Palmer* and the ice-strengthened ship *Laurence M. Gould*.

These projects, funded and managed by the National Science Foundation (NSF), are part of the international effort to understand the Antarctic and its role in global processes. NSF also supports research that can best be performed or can only be performed in Antarctica. Besides research projects, NSF's Office of Polar Programs (OPP), which manages the antarctic program, supports Teachers Experiencing Antarctica (TEA), which strives to create a polar learning community of teachers, students, school districts, and researchers. As part of their professional development, six teachers, which NSF selects competitively, will work with six research teams this austral summer. U.S. Antarctic Program investigators volunteer to include TEA participants in their field parties. Another OPP program—the Antarctic Artists and Writers Program—provides opportunities for painters, photographers, writers, and others to use serious writing and the arts to increase people's understanding of the Antarctic and America's heritage there.

The scientists conducting the projects come primarily from U.S. universities and have won NSF support by responding to the Antarctic Research Program Announcement and Proposal Guide (NSF 01–81; http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf02086/). Operational resources in Antarctica are also used to support scientists from other Federal agencies.

Science highlights

The following projects are among those supported in Antarctica this austral summer and winter. Where

applicable, links for additional information have been added. Information on NSF-funded science awards can also be found in the online NSF awards database. To access this information, search the awards database at http://www.fastlane.nsf.gov/a6/A6AwardSearch.htm. Each NSF award listed there includes the award number, which can be used to do a keyword search.

- **Long-term ecological research (LTER)**. Two sites in Antarctica-one in the McMurdo Dry Valleys and the other along the west coast of the Antarctic Peninsula centered on Palmer Station-are among the world's 25 NSF-sponsored LTER sites, which are being investigated to increase our understanding of ecological phenomena over long temporal and large spatial scales (all but one of the other sites are in the United States) (http://lternet.edu/).

- **West Antarctica GPS Network (WAGN):** Researchers this season will begin to deploy a series of Global Positioning System transceivers across the interior of the West Antarctic Ice Sheet — an area approximately the size of the contiguous United States from the Rocky Mountains to the Pacific coast. The ability to measure the motions of the Earth's crust in the bedrock surrounding and underlying the West Antarctic Ice Sheet is critical to understanding the past, present, and future dynamics of the ice sheet and its potential role in future global change scenarios, as well as improving the understanding of Antarctica's role in global plate motions. WAGN will complement existing GPS projects by filling a major gap in coverage among several discrete crustal blocks that make up West Antarctica — a critical area of potential bedrock movements.

- **West Antarctica GPS Network**. Researchers are deploying global positioning system (GPS) transceivers across the West Antarctic Ice Sheet-an area the size of the United States from the Rockies to the Pacific. Measurements of motions of the Earth's crust in the bedrock around and under the West Antarctic Ice Sheet are critical to understanding its dynamics and its potential role in global change, and they improve our understanding of Antarctica's role in global plate motions. This network complements existing GPS projects by filling a gap in coverage among the crustal blocks that make up West Antarctica (http://www.ig.utexas.edu/research/projects/gps/wais_bedrock/wais_bedrock.htm/).

- **International Transantarctic Scientific Expedition**. The U.S. component of the multiyear International Transantarctic Scientific Expedition (U.S. ITASE) is making the fourth of four traverses over the West Antarctic Ice Sheet this season. The aim is to understand the past 200 years of west antarctic climate and environmental change. Researchers are collecting shallow ice core and snow pit samples for ice chemical analyses, shallow and deep radar data to look at internal layer reflections and bedrock topography, atmospheric samples, and meteorological readings to understand the current climate of the ice sheet. The data contribute to our understanding the West Antarctic Ice Sheets of both today and the recent past (http://www.ume.maine.edu/USITASE/).

- **Historic huts**. Researchers are finding the biotic and nonbiotic agents that cause deterioration in historically significant huts built by antarctic explorers in the early 20th century. While the polar environment has protected some artifacts from rapid decay, degradation is still a concern. Conservators from the United States and New Zealand are studying mechanisms of decay, testing methods to control future deterioration, determining the extent of pollutants in soils at the sites, and evaluating chemical spills in the huts (https://www.fastlane.nsf.gov/servlet/showaward?award=9909271 [U.S. research grant from NSF]; http://www.antarcticanz.govt.nz/Pages/Logistics/ScienceEvent.msa/ [New Zealand project K-021]; http://www.newscientist.com/news/news.jsp?id=ns99993018 [*New Scientist* article, November 2002]).

- **Combustion effluent in the McMurdo Dry Valleys**. Antarctica is comparatively pristine, but the human presence there could possibly affect some science, so researchers are measuring carbonaceous aerosols ("black carbon") in the McMurdo Dry Valleys. The aerosols could come from diesel generators, from helicopters, or even from McMurdo Station itself (100 kilometers away). The data will help assess the impact of human activities and the benefit of converting to solar power at research camps. The units will transmit to the Internet until the end of the 2002-2003 season (Measurement of Combustion Effluent Carbonaceous Aerosols in the McMurdo Dry Valleys, Antarctica, Anthony D. Hansen, Magee Scientific

Company, NSF award OPP 98-15140).

- **South Pole Astrophysics:**Telescopes at the South Pole are continuing investigations into the origins of the universe (http://astro.uchicago.edu/cara/). For example, the degree angular scale interferometer (DASI), which has been measuring the cosmic microwave background (CMB) at the South Pole since the 1999-2000 season, has precisely measured minuscule variations in the afterglow of the Big Bang, verifying the theoretical framework that underlies the modern scientific concept of how the universe came into being. The discovery is so fundamental that it may also provide a key to an even keener understanding of the origins of the universe. In 2003, DASI will measure the currently undetected polarization of CMB anisotropy to test the standard theory of the early universe. Team members are reconfiguring DASI from 30 gigahertz (GHz) to 100 GHz for intensity and polarization measurements of the fine-scale CMB anisotropy power spectrum. (http://astro.uchicago.edu/dasi/).

- **Arcminute Cosmology Bolometer Array Receiver**. Advances that are revolutionizing cosmology include the Arcminute Cosmology Bolometer Array Receiver, which measures slight temperature differences in the CMB. Images to date in four frequency bands exploit the excellent millimeter and submillimeter atmospheric "windows" at the South Pole, providing a snapshot of the universe in its infancy and strongly constraining its possible constituents and structure. These detailed images, along with existing observations made by others, comprise a continuous and consistent description of primary CMB anisotropy. In this second season of observation, team members are operating and upgrading the instrument, preparing it for winter, and calibrating the previous winter's observations (http://cosmology.berkeley.edu/group/swlh/acbar/).

- **Snow megadunes**. Megadunes of the East Antarctic Ice Sheet are subtle features, which are 2 to 4 meters in amplitude over a 2- to 4-kilometer wavelength and have just recently begun receiving significant research attention. These megadunes may affect the interpretation of climate in deep ice cores. Investigators are conducting ground-penetrating radar surveys, global positioning surveys, firn cores, pit sampling, automatic weather station installation, and snow permeability experiments to determine the physical and chemical characteristics of the dunes to help us understand their significance, including their effect on ice cores (http://nsidc.org/antarctica/megadunes/).

Construction highlights

- **Science support center**. Phase 1 of a new science support center began operating at the beginning of the season. When completed, phase 2 will increase the effectiveness and efficiency of science support and will enable demolition of the existing science support facility (Building 58), one of McMurdo's oldest and least efficient structures.

- **Waste-heat recapture**. A multiyear project is under way to capture McMurdo power plant waste heat for
  - heating feedwater to the reverse-osmosis water plant, and
  - space-heating the science laboratory, dormitories, and other buildings.

- **Joint Space Operations Center**. This multistory building near the center of McMurdo Station, funded by the National Aeronautics and Space Administration and NSF, has been erected and when complete will enable consolidation of much of McMurdo's satellite ground station activities.

- **South Pole Modernization Project**. Major renovation is under way to replace most of the 26-year-old South Pole Station's central facilities, which have exceeded their design life and cannot meet projected science demands. To date, a new fuel storage facility, a new garage and shop, and a new electric power plant have become operational. Living facilities are being modernized, with construction of housing and food service wings of the new elevated station. Exteriors of wings that will house station services, medical facilities, and science labs were completed last season, with the interiors being completed during the winter. Additional wings are being erected this season. The station is scheduled for completion in 2007.

- **Palmer Station improvements**. An upgrade of the two major buildings at Palmer Station, lasting several years, has essentially been completed, increasing the effectiveness of science support and living facilities. A ground station installed in 2002 has extended the station's Internet communications to 24 hours a day.

U.S. Antarctic Program, 2002-2003
Sites of major activities

AERONOMY AND ASTROPHYSICS

After hours of delay, the winds shifted enough to launch the Long Duration Balloon at 12:30 a.m. on 21 December 2001. The 5,000-pound, high altitude balloon will circle Antarctica twice while recording atmospheric conditions that could provide clues to the galaxy's history and composition. *(NSF/USAP photo by Melanie Conner)*

The polar regions have been called Earth's window to outer space. Originally, this term applied to dynamic events like the aurora, staged as incoming solar plasmas encountered the Earth's geomagnetic fields. Its unique properties create a virtual screen of the polar upper atmosphere on which the results of such interactions can be viewed (and through which evidence of other processes can pass). During the mid-1980s, Earth's window was extended to refer to the "ozone hole" in the polar atmosphere. As scientists have verified an annual loss of ozone in the polar stratosphere, a window previously thought closed (stratified ozone blocking the Sun's ultraviolet rays) is now known to "open," consequent to chemical cycles in the atmosphere.

For astronomers and astrophysicists, the South Pole presents unique opportunities. Thanks to a minimum of environmental pollution and anthropogenic noise, the unique pattern of light and darkness, and the properties of the geomagnetic force field, scientists staging their instruments here can probe the structure of the Sun and the Universe with unprecedented precision. Studies supported by the Aeronomy and Astrophysics program explore three regions:

- **The stratosphere and the mesosphere:** In these lower regions, current research focuses on stratospheric chemistry and aerosols, particularly those implicated in the ozone cycle.

- **The thermosphere, the ionosphere, and the magnetosphere:** These higher regions derive many characteristics from the interplay between energetically charged particles (ionized plasmas in particular) and geomagnetic/geoelectric fields. The upper atmosphere, particularly the ionosphere, is the ultimate sink of solar wind energy transported into the magnetosphere just above it. This region is energetically dynamic, with resonant wave-particle interactions and joule heating from currents driven by electric fields.

- **The galaxy and the Universe beyond, for astronomical and astrophysical studies:** Many scientific questions extend beyond the magnetosphere, including a particular interest in the Sun and cosmic rays. Astrophysical studies are conducted primarily at Amundsen-Scott South Pole Station or on long-duration balloon flights launched from McMurdo Station. The capability of such balloons is expanding dramatically.

All research projects sponsored by this program benefit from (indeed, most require) the unique physical conditions found only in the high latitudes, yet their ramifications extend far beyond Antarctica. High-latitude astrophysical research contributes to the understanding of Antarctica's role in global environmental change, promotes interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves understanding of the critical processes of solar energy in these regions. Life exists in a balance on Earth because of numerous chemical and atmospheric phenomena that have developed in the specific atmosphere of this 4.6-billion-year-old spinning planet in orbit 149,637,000 kilometers from a middle-sized, middle-aged star. The 20th-century expansion of traditional astronomy to the science of astrophysics, coupled with the emerging discipline of atmospheric science (see also the Ocean and Climate Systems program), is nowhere better exemplified than in Antarctica.

AMANDA-Antarctic muon and neutrino detector array.
Robert Morse, University of Wisconsin.

The AMANDA project takes advantage of unique polar conditions to discover and probe the sources, both inside our galaxy and beyond, of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth. Neutrinos are elementary particles believed to have very little or no mass and no electrical charge. Coursing through the universe, they can take any of three forms and interact only rarely with other particles. Thus they arrive on Earth with potentially unique information about where they may have originated. They could be diffuse (made up of contributions from many active galactic nuclei) and may even be an indicator of the decomposition of the mysterious dark matter now believed to dominate the Universe. Or they could be single sources, such as supernova remnants, rapidly rotating pulsars, the gas around black holes, neutron stars, or individual blazars.

AMANDA is the largest detector of neutrinos in the world. During the past 5 seasons, the installation of over 600 photomultiplier tubes [embedded between 1 and 2 kilometers (km) into the ice and oriented downward] has established a natural detector of Cherenkov radiation in the ice. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) High-energy neutrinos with enough energy to pass through the Earth's mass may collide with an atomic nucleus in the ice or rock near the tubes. Such collisions produce a distinctive eerie blue glow, which the basketball-sized glass tubes can detect for up to several hundred meters through the clear ice.

Neutrino astronomy has previously been limited to the detection of solar neutrinos, plus one brief, spectacular burst from the supernova that appeared in the Large Magellanic Cloud in February 1987 (SN-1987a). In recent years, new sources of high-energy gamma rays have been discovered, among them Mrk-421, which was seen by the National Aeronautics and Space Administration's Compton Gamma Ray Observatory and the Mount Hopkins Observatory. AMANDA is designed to study just such objects, which are believed to emit copious numbers of high-energy neutrinos. Now that first-generation detectors such as AMANDA have been enhanced (the array may one day number 5,000 tubes strung on 80-some cables within 1 cubic km of ice), neutrino astronomy would appear to be on the verge of detecting high-energy particles that carry information from the outer edges of the universe. (AA-130-O; NSF/OPP 99-80474)

Advance thin ionization calorimeter (ATIC) science balloon payload.
John P. Wefel, Louisiana State University-Baton Rouge.

The advance thin ionization calorimeter (ATIC) balloon experiment is designed to use the National Aeronautics and Space Administration's Long-Duration Ballooning program for a series of antarctic balloon flights (each 10 to 14 days long) to investigate the composition and energy spectra of galactic cosmic rays (GCR) at the highest energies accessible from balloon platforms, the region up to ~1014 electronvolt (eV). If supernova remnants are, as widely believed, the cosmic accelerators for the GCR, it is in this high-energy region that we anticipate observing effects of the acceleration process.

The ATIC experiment, weighing 1,360 kg and consuming 400 watts of power, consists of three major detector systems: (a) a detector to measure the particle charge; (b) a three-layer, crossed scintillator strip hodoscope, interspersed within a carbon target, to measure the trajectory of the particle; and (c) a fully active bismuth germanate scintillation calorimeter to measure the energy of the hadronic cascade initiated by particle interactions in the carbon target. The individual detectors are read out with application-specific integrated circuit devices.

Previous pioneering experiments have indicated differences in the spectra of hydrogen, helium, and the heavier nuclei, leading to an energy-dependent composition. In addition, the "all-particle" GCR spectrum and composition, as measured by ground-based air shower arrays, show indications of changes in the energy regime approaching the well-known spectral "knee" at 1015-1016 eV. Our goal is to apply new experimental techniques to the study of these very-high-energy particles to verify previous reports and to search for the behavior expected from the supernova remnant acceleration process. (AB-143-O; NASA grant)

Long-duration balloon project.
William Stepp, National Aeronautics and Space Administration/National Scientific Balloon Facility.

As a means of high-altitude exploration, free-flying balloons have many advantages over satellites. Balloons remain in a specific location much longer, cost little to launch, and are designed to return their instruments safely to Earth. Balloons have been flying for two centuries, but until recently were limited by how long they could stay aloft. The latest scientific balloons, deployed from the National Scientific Balloon Facility (NSBF) in Palestine, Texas, are able to fly missions of 100 days or longer.

The current NSBF effort in Antarctica, known as the long-duration balloon (or LDB) program, launches high-altitude balloons carrying scientific payloads into the stratosphere. Many important scientific observations in fields such as hard x-ray/gamma ray and infrared astronomy, cosmic rays, and atmospheric studies have been made from balloons. (AB-145-O; NASA)

Boomerang-Long-duration balloon (B2K): A balloon-borne measurement of polarization in the cosmic microwave background.
John Ruhl, University of California-Santa Barbara.

Cosmic microwave background radiation (CMBR), which originated in the "big bang," is a relic left over from the early days of the Universe. The variations in the brightness on the sky of the CMBR carry the imprint of the distribution of matter about 300,000 years after its creation, and the linear polarization of the CMBR can provide information from even earlier times: that is, just a fraction of a second after creation.

We continue to analyze data gathered in 1998 from a long-duration balloon flight of Boomerang (a millimeter-wave sensitive telescope designed to image CMBR). As we progress, the analysis has larger sky coverage and continues to refine our measurement of the CMB angular power spectrum. The result is better constraints on the cosmological parameters. We are preparing for a second flight of this instrument in December 2002 to measure the polarization of the CMBR. Last year, we conducted successful integration tests at the National Scientific Balloon Facility, but a problem with detector construction has held up our deployment to Antarctica.

The new detectors that have been developed have displayed the target thermal and noise properties and have demonstrated good polarization properties. In addition, the two-color photometers have demonstrated excellent polarization properties as well. This second flight should add significantly to our knowledge about CMBR and the early days of the Universe. (AB-148-O; NSF/OPP99-80654)

The operation of an extremely-low-frequency/very-low-frequency radiometer at Arrival Heights, Antarctica.
A.C. Fraser-Smith, Stanford University.

Since it was discovered in the 1930s that natural phenomena emit the lowest form of electromagnetic energy (radio waves), the field of radio astronomy has joined the scientific effort to analyze both atmospheric and extraterrestrial signals. The extremely-low-frequency/very-low-frequency (ELF/VLF) record of data collected by this project at Arrival Heights-chosen because it is unusually free from manmade electromagnetic interference-now extends unbroken for almost 15 years.

The radiometers at McMurdo operate in both the ELF and VLF ranges, monitoring radio noise from natural sources such as thunderstorms. Characterizing the possible sources of radio interference is important for operational purposes. Since thunderstorms generate telltale radio signals, tracking variations in global noise reflects thunderstorm activity and thus can provide information on changes in global climate.

The Arrival Heights site is one of a network of eight such radiometers operated by Stanford University for the Office of Naval Research. (AO-100-O; NSF/OPP 01-38126)

Magnetometer data acquisition at McMurdo and Amundsen-Scott South Pole Stations.
Louis J. Lanzerotti, Bell Laboratories, Lucent Technologies, and New Jersey Institute of Technology, and Al Weatherwax, Siena College.

The magnetosphere is that region of space surrounding a celestial object (such as the Earth or other planets) where the object's magnetic field is strong enough to trap charged particles. Magnetometers have been installed at selected sites in both polar regions to measure changes in the magnitude and direction of Earth's magnetic field. These changes can arise from a number of causes and are often due to magnetohydrodynamic waves in the magnetosphere. The unique climatic conditions in Antarctica permit scientists to view the atmosphere optically (see project AO-104-O) and to correlate such changes in hydromagnetic waves with the optical emissions caused by charged particles that precipitate from the trapped radiation of the Earth into the upper atmosphere.

In this project, we are measuring such variations with magnetometers installed at conjugate sites in both hemispheres: at McMurdo Station and Amundsen-Scott South Pole Station, Antarctica, and (in collaboration with colleagues) at sites in Canada, including Iqaluit (Northwest Territories). The antarctic systems gather unique data related to the coupling of the interplanetary medium into the dayside magnetosphere, including the magnetospheric cusp region. The data also provide insights into the causes and propagation of low-frequency

hydromagnetic waves throughout the magnetosphere.

The antarctic magnetometers continue to measure with high reliability the magnitude and the direction of the variations of the field in the frequency range from about 0 to about 0.1 Hertz, with a resolution of about one nanoTesla. In addition to the research involving the conjugate data, these antarctic data are being analyzed in the context of other concurrent data gathered by the six U.S. automatic geophysical observatories that are a part of the polar experiment network for geophysical upper atmosphere investigations (or PENGUIN) program (see project AO-112-O) and data acquired by other nations in the Antarctic. (AO-101-O; NSF/OPP no number)

High-latitude magnetic pulsations.
Mark Engebretson, Augsburg College, and Roger Arnoldy, University of New Hampshire.

The Earth's magnetic field arises from its mass and motion around the polar axis, but it creates a powerful phenomenon at the edge of space known as the magnetosphere, which has been described as a comet-shaped cavity or bubble around the Earth, carved in the solar wind. When that supersonic flow of plasma emanating from the Sun encounters the magnetosphere, the result is a long cylindrical cavity, flowing on the lee side of the Earth, fronted by the blunt nose of the planet itself. With the solar wind coming at supersonic speed, this collision produces a "bow shock" several Earth radii in front of the magnetosphere proper.

One result of this process is fluctuations in the Earth's magnetic field, called micropulsations, which can be measured on time scales between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic regions) to learn more about how variations in the solar wind can affect the Earth and manmade systems.

We will study these solar-wind-driven variations and patterns at a variety of locations and over periods up to a complete solar cycle. Since satellite systems are now continuously observing solar activity and also monitoring the solar wind, it is becoming feasible to develop models to predict the disruptions caused by such magnetic anomalies. And while our work is geared specifically toward a better understanding of the world and the behavior of its manmade systems, it will also involve space weather prediction. (AO-102-M/S; NSF/OPP 99-09212)

Antarctic auroral imaging.
Stephen Mende, Lockheed Palo Alto Research Laboratory.

Scientists are only beginning to try quantitative studies on the dynamic behavior of the magnetosphere. In the past, detail-oriented explorations with space satellites have enabled them to map the average distribution of magnetospheric energetic particle plasma content. But the dynamics of auroral phenomena-what happens when particles from the magnetosphere precipitate into the atmosphere, producing fluorescence-have been hard to quantify through optical means. Amundsen-Scott South Pole Station is uniquely situated to observe aurora because the darkness of the polar winter permits continuous optical monitoring; at most other sites, the sky becomes too bright near local mid-day.

The aurora can actually be regarded as a two-dimensional projection of the three-dimensional magnetosphere, because particles tend to travel along the magnetic field line. By observing the dynamics and morphology of the aurora, scientists get a reliable glimpse into the dynamics of the region of the three-dimensional magnetosphere associated directly with it. This method relies on knowledge relating the type of aurora both to specific energies of precipitation and to specific regions of the magnetosphere.

We are deploying an intensified optical, all-sky imager (operating in two parallel wavelength channels, 4,278 and 6,300 Angstroms) to record digital and video images of auroras in the winter darkness. These wavelength bands allow us to discriminate between more and less energetic electron auroras and other precipitation. The South Pole Station observations of the polar cap and cleft regions entail measuring auroral precipitation patterns and then interpreting the results in terms of the coordinated observations of magnetic radio-wave absorption images as well as high-frequency coherent-scatter radar measurements.

We expect this work to provide insight into the sources and energization mechanisms of auroral particles in the magnetosphere, as well as other forms of energy inputs into the high-latitude atmosphere. (AO-104-O; NSF/OPP 98-18086)

Extremely-low-frequency/very-low-frequency waves at the South Pole.
Umran Inan, Stanford University.

Atmospheric scientists orient their studies around different strata, or regions, and the boundaries and interactions between these regions are of particular interest. How are the upper atmosphere regions coupled electrodynamically? What can we learn by measuring the energy that is being transported between the magnetosphere and the ionosphere? These are only two of the questions the U.S. Antarctic Program's automatic geophysical observatory (AGO) program is designed to explore. Plasmas occur in the magnetosphere and the ionosphere, and they can be transported and accelerated by a variety of different wave-particle interactions. One important dynamic in this system is particle precipitation that is driven by extremely-low-frequency/very-low-frequency (ELF/VLF) waves. Thus, measuring ELF/VLF waves from the multiple sites of the AGO network provides a powerful tool for remote observations of magnetospheric processes.

This project maintains a system at Amundsen-Scott South Pole Station to measure magnetospheric ELF/VLF phenomena and to correlate the data with measurements made by the AGO system. (AO-106-S; NSF/OPP 99-09872)

Study of polar stratospheric clouds by LIDAR.
Alberto Adriani, Instituto di Fisica dell'Atmosfera, Rome, Italy.

The appearance each spring of the stratospheric ozone hole above Antarctica is driven by chlorine compounds interacting on the surfaces of clouds that formed the previous polar winter; these are known as polar stratospheric clouds (PSC). This interaction is one explanation of why ozone depletion is much more severe in polar regions than elsewhere.

This project uses an optical radar (LIDAR, light detection and ranging) to study the PSC, stratospheric aerosol and the thermal behavior and dynamics of the atmosphere above McMurdo Station. Continuous LIDAR observations provide insight into the formation, evolution, and other peculiar characteristics of these PSC.

Such an observational activity is also performed in the framework of the Network for the Detection of Stratospheric Change (NDSC), a global set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the atmosphere (see www.ndsc.ws on the Internet). McMurdo Station is considered a primary NDSC site for LIDAR observations and for the monitoring of aerosol and clouds in the stratosphere. Such data also provide a complement to the information gained from the balloon-borne instruments of project AO-131-O, and thus collaborative activities are being coordinated with the University of Wyoming. (AO-107-O; NSF/OPP 90-17805)

A very-low-frequency beacon transmitter at the South Pole.
Umran Inan, Stanford University.

This 3-year project to establish and operate a very-low-frequency (VLF) beacon transmitter at the South Pole will measure solar effects on the Earth's mesosphere and lower ionosphere. Relativistic electrons, measured at geosynchronous orbit to have energies of more than 300 kiloelectronvolts, appear to fluctuate in response to substorm and solar activity. During such events, these highly energetic electrons can penetrate as low as 30 to 40 kilometers above the Earth's surface. At that altitude, they can wreak havoc in the atmosphere: they ionize chemical species, create x rays, and may even influence the chemistry that produces ozone.

By comparing how the South Pole VLF signal varies in both amplitude and phase when it arrives at various antarctic stations, the extent of relativistic electron precipitation can be calculated. The transmitter will also produce other data on solar proton events, relativistic electron precipitation from the Earth's outer radiation belts, and the joule heating components of high-latitude/polar cap magnetosphere/ionosphere coupling processes.

VLF data from the South Pole beacon provide a valuable complement to two other efforts: first, to other antarctic upper atmospheric research, such as the automatic geophysical observatory programs and the Southern Hemisphere coherent high-frequency radar Super4 Dual Auroral Network (SUPERDARN) and second, to ongoing satellite-based measurements of trapped and precipitating high-energy electrons at both high and low altitudes. The latter are collected by the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX). (AO-108-O; NSF/OPP 00-93381)

South Pole Air Shower Experiment-2.
Thomas Gaisser, Tudor Stanev, and Timohty Miller, University of Delaware; and Albrecht Karl, University of Wisconsin-Madison.

Cosmic rays consist of protons and other atomic nuclei, accelerated (scientists believe) to high energy levels in such distant astrophysical sources as the remnants of supernovas. As cosmic rays arrive at Earth from space, they interact in the upper atmosphere. The South Pole Air Shower Experiment-2 (SPASE-2) is a sparsely filled array of 120 scintillation detectors spread over 15,000 square meters at the South Pole. This array detects the charged particles (primarily electrons) that are produced by interactions of these very-high-energy cosmic rays.

A nine-station subarray called VULCAN has been constructed to detect the Cherenkov radiation produced high above the ground in the same showers. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) The SPASE-2 array is located less than half a kilometer from the top of AMANDA (the antarctic muon and neutrino detector array) and is designed to complement its neutrino detecting capacity (see project AA-130-O). SPASE-2 has two goals:

First, it is intended to investigate high-energy primary (galactic in origin) cosmic radiation, by determining the relative contribution of different groups of nuclei at energies greater than about 100 teraelectronvolts. This can be done by analyzing coincidences between SPASE-2 and AMANDA. Such coincident events are produced by high-energy cosmic ray showers with trajectories that pass through SPASE-2 (on the surface) and AMANDA (buried 1.5 to 2 kilometers beneath it). AMANDA detects the high-energy muons penetrating the Earth in those same showers for which SPASE-2 detects the low-energy electrons arriving at the surface. The ratio of muons to electrons depends on the mass of the original primary cosmic ray nucleus. The VULCAN detector further permits the calculation of two other ratios that also depend on primary mass in readings from the showers it detects.

Second, it is intended to use the coincident events as a tagged beam. This construction permits us to investigate and calibrate certain aspects of the AMANDA response. This project is performed in cooperation with the University of Leeds in the United Kingdom. (AO-109-O; NSF/OPP 99-80801)

High-latitude antarctic neutral mesospheric and thermospheric dynamics and thermodynamics.
Gonzalo Hernandez, University of Washington.

The South Pole is a unique and interesting spot from which to observe the dynamic motion of the atmosphere. The fact that it is on the axis of the Earth's rotation strongly restricts the types of wave motion that can occur there, compared with sites at lower latitudes. Antarctica attracts atmospheric scientists for many reasons; a primary draw is that neutral winds perforce can only blow across the Earth's rotational axis. This simple condition has a profound influence on the large-scale dynamics of the atmosphere at high latitudes, since only zonal wave-number one mode horizontal motions are possible.

The resulting simplifications may clarify the behavior of the global atmosphere. For example, how do scientists measure the wind speed of the atmosphere? One direct method is by determining the doppler shift of naturally occurring emissions in the upper atmosphere as they flow along at predictable heights. Hydroxyl radicals, for example, are confined to a fairly narrow band near 90 kilometers of altitude.

This study uses a high-resolution Fabry-Perot interferometer (located at Amundsen-Scott South Pole Station) to make simultaneous azimuthal observations of the individual line spectra of several upper atmospheric trace species, especially the hydroxyl radical and atomic oxygen. The observed doppler shift of the emission lines provides a direct measure of line-of-sight wind speed, while the wind field structure can also be derived from these multi-azimuth measurements. In addition, the simultaneously observed line widths provide a direct measurement of kinetic temperature. (AO-110-M/S; NSF/OPP 99-09743)

Riometry in Antarctica and conjugate regions.
Theodore Rosenberg and Allan Weatherwax, University of Maryland.

We propose to continue studying the polar ionosphere and magnetosphere from Antarctica and nominally conjugate regions in the Arctic. High-frequency cosmic noise absorption measurements (riometry) and auroral luminosity measurements (photometry) will form the basis of our investigations, which will involve extensive collaboration with other researchers using complementary data sets.

We will continue to maintain imaging and broadbeam riometers and two-wavelength zenith photometers at South Pole and McMurdo Stations. In addition, we will continue to provide the data acquisition systems at both stations for the common recording of other geophysical data and their dissemination to collaborating investigators. To enhance the usefulness and timeliness of these data, we will maintain a homepage from which the general scientific community can access these antarctic data sets on a daily basis and, by special arrangement, in near real time. Imaging riometer measurements will also be continued at Iqaluit, Northwest Territories, Canada, which is the nominal magnetic conjugate point of South Pole Station.

Our activities will enable us to participate in, and contribute to, several major science initiatives, including the GEM, CEDAR, ISTP/GGS, and National Space Weather programs. A primary focus of our analysis over the next year will be coordinated ground- and satellite-based studies of Sun-Earth connection events. The overall objective is to understand the relevant physical processes that produce the observed phenomena and how they relate to internal and external driving forces (magnetospheric/ionospheric instabilities and solar wind/IMF variations, respectively). From this may emerge an enhanced capability to predict the possible occurrence of

events that might have negative technological or societal impacts sufficiently in advance to lessen their effects. (AO-111-M/S; NSF/OPP 00-03881)

Polar experiment network for geophysical upper atmosphere investigations (PENGUIN).
Theodore Rosenberg, University of Maryland-College Park.

Continued progress in understanding the Sun's influence on the structure and dynamics of the Earth's upper atmosphere depends on increasing knowledge of the electrodynamics of the polar cap region and the key role this region plays in coupling the solar wind with the Earth's magnetosphere, ionosphere, and thermosphere. Measurements that are central to understanding include the electric field convection pattern across the polar cap and knowledge of the response of the atmosphere to the many forms of high-latitude wave and particle energy inputs during both geomagnetically quiet and disturbed situations.

The U.S. automatic geophysical observatory (AGO) network, which consists of a suite of nearly identical instruments (optical and radio wave auroral imagers, magnetometers, and narrow- and wide-band radio receivers) at locations on the polar plateau, actively studies the coupling of the solar wind to ionospheric and magnetospheric processes, emphasizing polar cap dynamics, substorm phenomena, and space weather.

When combined with measurements made at certain staffed stations, AGO network data facilitate both large- and small-scale studies of the energetics and dynamics of the high-latitude magnetosphere. The research will be carried out with in situ observations of the geospace environment by spacecraft, in close cooperation with other nations working in Antarctica and in conjunction with studies performed in the Northern Hemisphere. (AO-112-O; no NSF/OPP award number)

Mapping the sound speed structure of the Sun's atmosphere.
Stuart M. Jeffries, University of New Mexico.

We will observe the velocity and intensity signals from the solar surface, using magneto-optical filters tuned to particular solar absorption lines formed in the midchromosphere and near the base of the photosphere, respectively. We will use a time-distance analysis of the high-frequency component of the observed signals to produce detailed maps of the time it takes acoustic waves to travel across the lower part of the solar atmosphere. The travel-time measurements will then be inverted to give maps that will show how the speed of sound changes in the solar atmosphere, both with location and time. These data will provide a stringent test bed for current models of the solar atmosphere and will almost certainly result in major improvements to these models.

The project provides an important first step toward being able to map the acoustic and magnetic properties of the Sun's atmosphere in three dimensions. Such data will be invaluable in our quest to understand how the Sun affects life on Earth. (AO-115-O; NSF/OPP 00-87541)

Auroral dynamics by the all-sky-imager at Amundsen-Scott South Pole Station.
Masaki Ejiri, National Institute of Polar Research, Japan.

The South Pole is a unique platform for observing aurora during the austral winter season. As a point on the Earth's rotational axis, the pole provides a unique vantage to observe the airglow and to discern the characteristics of acoustic gravity waves in the polar region as they vary in altitude and wavelength. Observing aurora continuously over the 24 hours in a day allows us to collect data on

- the dayside polar cusp/cleft aurora (due to the direct entry of the solar wind);
- afternoon aurora that are closely associated with the nightside magnetospheric storm/substorm activities; and
- the polar cap aurora, which depends on the polarity of the interplanetary magnetic field.

Research has shown that these auroras develop from precipitating low-energy particles entering the magnetosphere from the solar wind.

Though data have been gathered at the South Pole since 1965 with a film-based, all-sky camera system, newer technology now produces digital images and permits us to process large amounts of information automatically. Currently, we are using the all-sky-imager, a digital charge coupled device imager monitored and controlled by the National Institute of Polar Research in Japan.

These international collaborations should enhance knowledge of the magnetosphere, the ionosphere, and upper/middle atmosphere physics. The high-frequency radar installations at Halley Bay, Sanae, and Syowa Stations provide the vector velocity of ionospheric plasma over the South Pole. These studies should provide further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar wind effects-specifically dayside auroral structure, nightside substorm effects, and polar cap arcs. (AO-117-O; U.S.-Japanese cooperative project)

Solar and heliosphere studies with antarctic cosmic ray observations.
John Bieber, University of Delaware.

Cosmic rays-penetrating atomic nuclei and electrons from outer space that move at nearly the speed of light-continuously bombard the Earth. Colliding with the nuclei of molecules found in the upper atmosphere, they create a cascade of secondary particles that shower down on Earth. Neutron monitors deployed in Antarctica provide a vital three-dimensional perspective on this shower and how it varies along all three axes. Accumulated neutron-monitor records (begun in 1960 at McMurdo Station and in 1964 at Amundsen-Scott South Pole Station) provide a long-term historical record that supports efforts to understand the nature and causes of solar/terrestrial and cosmic ray variations as they are discerned over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales.

This project continues a series of year-round observations at McMurdo and Amundsen-Scott South Pole Stations recording cosmic rays with energies in excess of 1 billion electronvolts. These data will advance our understanding of a number of fundamental plasma processes occurring on the Sun and in interplanetary space. At the other extreme, we will study high time-resolution (10-second) cosmic ray data to determine the three-dimensional structure of turbulence in space and to elucidate the mechanism by which energetic charged particles scatter in this turbulence. (AO-120-M/S; NSF/OPP 98-16129)

A versatile electromagnetic waveform receiver for South Pole Station.
James LaBelle, Dartmouth College, and Allan Weatherwax, Siena College.

The Earth's aurora naturally emits a variety of low-frequency (LF), MF (medium-frequency), and high-frequency (HF) radio waves that are signatures of the interaction between the auroral electron beam and the ionospheric plasma. Yet some of the mechanisms that generate plasma waves are not well understood. This project focuses on several types of signals detectable at ground level, including auroral hiss, which occurs primarily at very low frequencies but often extends into the LF/MF range, and auroral roar, a relatively narrowband emission generated near or at the second and third harmonics of the electron cyclotron frequency.

We will use a versatile electromagnetic waveform receiver deployed at South Pole Station. Only recently has it been possible to conceive of an inexpensive, versatile receiver of this type for the South Pole. An antarctic location is essential for ground-based observations of LF auroral hiss, because the broadcast bands usually found in the Northern Hemisphere are typically absent in Antarctica. Also, the absence of broadcast bands improves the effectiveness of automatic wave-detection algorithms.

We can use the receiver to address many issues. For example, it has recently been discovered that auroral roar is sometimes modulated at frequencies between 7 and 11 Hertz, a phenomenon called flickering auroral roar. This receiver will allow us to find out how common flickering auroral roar is, the conditions under which it occurs, what the frequencies are, and how the amplitude and frequency vary over time.

Between 15 percent and 30 percent of auroral hiss events are not observable at very low frequencies. The receiver will determine whether LF auroral hiss consists exclusively of relatively unstructured broadband impulses or whether it sometimes displays a fine structure similar to that of auroral kilometric radiation and whistler-mode waves in the same frequency range detected in the lower ionosphere. We will also define and test auroral roar and auroral hiss mechanisms. Despite its extensive application for communications, the LF/MF/HF band has been relatively little investigated as a source of natural radio emissions detectable at ground level.

A complete knowledge of our geophysical environment requires understanding the physics of these emissions. Further, electron beam-plasma interactions analogous to the terrestrial aurora occur in many space physics and astrophysics applications. Often, the electromagnetic radiation emitted by these systems is our only source of knowledge about them. The local auroral plasma provides an opportunity to view some plasma radiation processes at close range. (AO-128-O; NSF/OPP 00-90545)

Effects of enhanced solar disturbances, during the 2000-2002 solar-max period, on the antarctic mesosphere-lower-thermosphere (MLT) and F regions composition, thermodynamics, and dynamics.
Gulamabas Sivjee, Embry Riddle Aeronautical University.

While variations in the Sun's energy affect people in obvious ways by driving the weather and the seasons, there are actually many cycles and variations of deeper interest to science, on scales from seconds to centuries to eons. One of the most basic is the 11-year cycle when the Sun's magnetic poles reverse direction (since reliable observations began, 23 of these have occurred and the last has just recently peaked), and sunspots and other solar activity wax to peak levels. The National Aeronautics and Space Administration is using this opportunity to conduct its TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite study, which will focus on the region between 60 and 180 kilometers above the Earth's surface.

Taking advantage of the timing of both of these events, we will use observations in the visible and near-infrared ranges of upper-atmospheric emissions above South Pole Station to study the heating effects of auroral electrical currents in the ionosphere, as well as planetary waves and atmospheric tides.

As it passes overhead, TIMED will provide data on the temperature, winds, and tides of the Earth's upper atmosphere, especially above the poles. But tracking satellites often have difficulty differentiating between variations in location or time. South Pole ground-based observations will be valuable in sorting out the time-location question. (AO-129-O; NSF/OPP 99-09339)

Measurements of polar stratospheric clouds, condensation nuclei, and ozone during the austral winter and spring.
Terry Deshler, University of Wyoming.

The stratospheric ozone layer provides an essential shield against solar ultraviolet radiation. The discovery in 1985 of large seasonal ozone losses above Antarctica took the world and the scientific community by surprise. Since that time, the cause of this unprecedented ozone loss has been identified, and governmental and commercial controls are in place to reduce the stratospheric chlorine load. However, while the overall cause of these large ozone losses is understood, many details must still be clarified before we can comprehensively model the stratospheric ozone balance. An international experiment to address some of these details will be undertaken from June through October of 2003. This experiment will compare balloon-borne ozone observations from nine antarctic stations (South Pole, General Belgrano II, Dumont d'Urville, Vicecomodoro Marambio, Georg von Neumayer, Rothera, Syowa, Davis, and McMurdo) with several three-dimensional transport models. The balloon releases will be coordinated to sample air parcels previously sampled at another location. Comparing the ozone changes within these air parcels, as they are tracked around the continent, provides an excellent test of our understanding of stratospheric chemistry. Similar experiments have been completed in the Arctic, but this is the first opportunity in the Antarctic.

The observations from McMurdo Station will also add to our database of annual profiles of ozone in late winter and spring. These observations will be completed as stratospheric chlorine levels are peaking and will provide, at a minimum, a basis for detecting the first signs of zone recovery. Such vertical ozone profiles constitute one of the crucial tools needed to observe the first signs of recovery following the decline in stratospheric chlorine. These measurements are archived in the database of the Network for the Detection of Stratospheric Change.

In addition to these ozone observations, we will extend our in situ observations of polar stratospheric clouds (PSCs). PSC instruments provide estimates of the size and concentration of the particles that form in these clouds. Heterogeneous chemistry-which activates chlorine so that it can then destroy ozone-occurs on the surface of such particles. These measurements provide estimates of the surfaces available for heterogeneous chemistry, of the rates of denitrification and dehydration, and of particle composition. We will continue our collaboration with the LIDAR (light detection and ranging) PSC measurements being taken at McMurdo Station (see project AO-107-O). (AO-131-O; NSF/OPP 99-80594)

In-situ measurements of halogen oxides in the troposphere.
Linnea Avallone, University of Colorado-Boulder.

This project includes research into the role of halogen oxides in tropospheric chemistry, as well as the development of two graduate courses-a laboratory experience based on observations of tropospheric trace gases and a professional development seminar-to enhance the current curriculum in atmospheric and oceanic sciences at the University of Colorado.

To investigate the role of halogen oxides in the chemistry of the troposphere, an in-situ instrument employing a low-pressure chemical conversion/resonance fluorescence technique will be deployed in the boundary layer and the free troposphere at various sites, including Niwot Ridge, Colorado; Bremen, Germany; and McMurdo Station, Antarctica. Each site has been chosen because of its unique location and facilities and with the goal of detecting these oxides under a variety of environmental and meteorological conditions. For these activities, the in-situ instrument will be augmented by a meteorological measurement system, which provides data on temperature, pressure, relative humidity, and wind direction and speed, plus an ozone analyzer.

Further, two new courses in the atmospheric and oceanic sciences will be designed and implemented. The first will be an inquiry-based laboratory course for upper-division undergraduates and beginning graduate students. This course will build on the resources available within the campus and surrounding atmospheric sciences communities to acquaint students with the nature and practice of experimental science. In addition, the course

will offer an opportunity for students to acquire and improve career skills in teamwork and in oral and written communication.

The second course, a seminar-style professional development class, will be designed to better prepare graduate students for the array of academic and nonacademic jobs available to them after they receive their degrees. This class will expose students to topics such as ethics in research, methods for writing and reviewing papers and proposals, and resources for improving teaching skills. Speakers from industry, national laboratories, community colleges, and so on, will be invited to help students explore the various avenues their careers might take. (AO-132-O; NSF/ATM 98-75829)

The measurement and analysis of extremely-low-frequency waves at South Pole Station.
Marc R. Lessard, Dartmouth College, and James LaBelle, Dartmouth College.

This project aims to detect and record magnetic field fluctuations in the extremely-low-frequency (ELF) range at South Pole Station, specifically auroral ion cyclotron waves, which have been well correlated with flickering aurora. Theory predicts that these waves modulate precipitating electron fluxes, thereby causing the flickering in luminosity emissions. Substantial evidence now supports this theory, although the excitation mechanism responsible for the ion cyclotron waves is somewhat uncertain. Perhaps the most well developed theory suggests that the waves result from an electron-beam instability. In any case, the frequency of the flickering or, equivalently, the frequency of the ground-based observations of ion cyclotron waves can be used to infer the altitude of the excitation mechanism, since the wave frequency depends on the strength of the background magnetic field, which is a known quantity. As such, the information that will be acquired can be used to test models of auroral acceleration mechanisms, as well as study dispersive ELF waves, a type of wave that has been reported in the literature only a few times, but one that may provide important information on substorm onset or, perhaps, the boundaries of open and closed magnetic fields.

A first step is to identify the wave mode and to determine the location and geomagnetic conditions under which these waves can be observed. The equipment used to make these observations consists of an induction coil magnetometer and data acquisition system. The induction coil is a commercially available device, one that was originally designed for geophysical exploration. Data will be returned to Dartmouth College for analysis. (AO-136-O; NSF/OPP 01-32576)

Dynamics of the mesosphere and lower thermosphere using ground-based radar and TIMED instruments.
Susan K. Avery, University of Colorado-Boulder.

This is a propitious time to study a number of atmospheric phenomena, because the 11-year solar cycle recently peaked and because of the National Aeronautics and Space Administration's (NASA's) TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite mission (see project AO-129-O). In addition to measurements derived from instruments on TIMED, we are installing a meteor radar at Amundsen-Scott South Pole Station. Concentrating on the dynamics of the mesosphere and lower thermosphere, we are looking at

- the space-time decomposition of wave motions,
- the delineation of the spatial climatology over Antarctica with emphasis on the structure of the polar vortex,

- the dynamic response to energetic events, and interannual variability.

The proposed meteor radar is a very-high-frequency system capable of measuring the spatial structure and temporal evolution of the horizontal wind field over the South Pole. Spatial climatology data will also come from existing ground-based radar at Davis Station, Syowa Station, Rothera Station, and the Amundsen-Scott base.

As NASA's TIMED satellite orbits over the South Pole, wind and temperature data will provide counterpoint and corroborative information. Thus, experiments based both in space and on the ground can be mounted, and data that previously relied on a single source can be better validated. (AO-284-O; NSF/OPP 00-00957)

Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere.
Umran Inan, Stanford University.

Tracking dynamic storms is a challenge, but lightning associated with thunderstorms can provide scientists with an indirect way of monitoring global weather. This project employs very-low-frequency (VLF) radio receivers located at Palmer Station; these are operated in collaboration with the British and Brazilian Antarctic Programs, both of which have similar receivers. All are contributors to the Global Change Initiative.

The VLF receivers measure changes in the amplitude and phase of signals received from several distant VLF transmitters. These changes follow lightning strokes because radio (whistler) waves from the lightning can cause very energetic electrons from the Van Allen radiation belts to precipitate into the upper atmosphere. This particle precipitation then increases ionization in the ionosphere, through which the propagating VLF radio waves must travel. Because the orientations to the VLF transmitters are known, it is possible to triangulate the lightning sources that caused the changes. Once the direction of the lightning source is known, it can be subjected to waveform analysis and used to track-remotely-the path of the thunderstorms.

The data will also be correlated with data from the antarctic Automatic Geophysical Observatory network and will be used by scientists studying the magnetosphere and the ionosphere. (AO-306-P; NSF/OPP 99-10565)

Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
Anthony Stark and Adair Lane, Smithsonian Institution Astrophysical Observatory; Christopher Walker, University of Arizona; James Kooi, California Institute of Technology; and Richard Chamberlin, California Institute of Technology Submillimeter Observatory.

Astronomy is undergoing a revolutionary transformation, where for the first time we can observe the full range of electromagnetic radiation emitted by astronomical sources. One of the newly developed and least explored bands is the submillimeter, at frequencies from about 300 giga-Hertz up into the tera-Hertz range. Submillimeter-wave radiation is emitted by dense gas and dust between the stars, and submillimeter-wave observations allow us to study in unprecedented detail the galactic forces acting on that gas and the star formation processes within it.

The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a 1.7-meter, single-dish instrument that has been operating for 6 years in several submillimeter bands. It has made position-position-velocity maps of submillimeter-wave spectral lines with arcminute resolution over regions of sky that are several square degrees in size. AST/RO provides a valuable complement to the planned arrays, which are inefficient when observing large areas because of their small field of view. AST/RO can observe molecular clouds throughout the fourth quadrant of the Milky Way and the Magellanic Clouds to locate star-forming cores and study in detail the dynamics of dense gas in our own galaxy. AST/RO studies are showing how molecular clouds

are structured, how the newly formed stars react back on the cloud, and how galactic forces affect cloud structure. They have also shown that the structure of molecular clouds is affected by their heavy element content and by their proximity to spiral arms, have studied the gradient of heavy elements in the galaxy, and have recently observed deuterated water to better understand the chemistry of water in dense clouds.

Essential to AST/RO's capabilities is its location at Amundsen-Scott South Pole Station. Most submillimeter radiation is absorbed by irregular concentrations of atmospheric water vapor before it reaches the Earth's surface. The desiccated air over South Pole Station allows an accurate intercomparison of submillimeter-wave power levels from locations on the sky separated by several degrees. This is essential to the study of submillimeter-wave radiation on the scale of the Milky Way and its companion galaxies.

We will devote equal effort to three initiatives: large-scale maps of emissions in the Galactic Center and the Magellanic Clouds (these will be made freely available), support of proposals from the scientific community, and installation and use of the detector systems currently under development. (AO-371-O; NSF/OPP 01-26090)

Degree angular scale inferometer: Cosmic microwave background anistropy polarization and fine-scale structure.
John Carlstrom, University of Chicago.

We plan to continue cosmological observations with the degree angular scale interferometer (DASI), which was first deployed at the Amundsen-Scott South Pole Station during the 1999-2000 austral summer. DASI is providing continuous high-quality measurements of the cosmic microwave background (CMB) radiation anisotropy over the critical range of angular scales spanning the first three acoustic peaks in the CMB power spectrum. The data are transferred daily to the University of Chicago, where analysis is keeping pace with the data rate. Plans are to publish the resulting power spectrum by the end of the year.

During the next austral winter, we will use DASI to measure the currently undetected polarization of the CMB anisotropy. The measurements will provide a critical test of the standard theory of the early Universe. The observations will also be done using full Stokes parameters, allowing a measurement of the cross-correlation of total intensity and polarization anisotropy. We will also construct new receiver components to reconfigure DASI from 30 giga-Hertz (GHz) to 100 GHz for intensity and polarization measurements of the fine-scale CMB anisotropy power spectrum. These new capabilities will allow detailed observations of the Sunyaev-Zel'dovich Effect (SZE) in nearby galaxy clusters and allow SZE surveys from massive clusters.

These proposed efforts complement other ongoing and planned CMB experiments with instruments in Chile and at the South Pole. These three instruments can view the same region of the sky and will provide detailed power spectra over this angular range, thereby gathering crucial data for understanding foreground contamination. These three instruments, working together, will allow this essentially unexplored but theoretically important portion of the CMB anisotropy power spectrum to be fully determined.

Outreach and education related to the project will be disseminated and implemented through established structures and mechanisms. These programs, which reach out to local and distant K-12 schoolteachers and students, will use the excitement of exploring our Universe to help attract women and minorities to science. Also, graduate and undergraduate education and research will be integrated into the construction of the instrumentation, as well as the data analysis. (AO-373-O; NSF/OPP 00-94541)

Mapping galactic magnetic fields with the submillimeter polarimeter for antarctic remote observations (SPARO).

Giles Novak, Northwestern University.

The submillimeter polarimeter for antarctic observations (SPARO) maps interstellar magnetic fields by measuring the linear polarization of submillimeter thermal emission from magnetically aligned interstellar dust grains. Interstellar magnetic fields are generally difficult to observe, especially in the dense regions to which SPARO is most sensitive. It is important to study these fields because their energy density is comparable to that of the other physical ingredients that are found in interstellar regions, so they can play important roles in the physical processes that occur there. This program is designed to contribute to our understanding of two general problems in which interstellar gas (and probably magnetic fields as well) has an important role: in the study of the Galactic Center region and star formation.

The study of the super-massive black holes that are found at the centers of many galaxies is motivated in part by our desire to understand the behavior of nature in such extreme environments and in part by the likely influence of these active galactic nuclei on the evolution of galaxies and perhaps of the Universe. Also, magnetic fields in star-forming regions may help support star-forming clouds against gravity, or they may help clouds collapse via angular momentum transfer. The SPARO instrument is operated on the Viper 2-meter telescope at the South Pole. Observations are carried out by personnel who remain there for the 8-month winter when South Pole Station is inaccessible. These observations are complementary to submillimeter polarimetry that is being carried out by larger telescopes at Mauna Kea, but SPARO is much more sensitive to submillimeter emissions because of the exceptionally good atmosphere transmission and the stability of the winter skies over the antarctic plateau.

Therefore, our observations are specifically aimed at (a) confirming SPARO's recent discovery of a large-scale toroidal magnetic field at the Galactic Center, (b) testing a magnetic outflow model for the Galactic Center Lobe, a radio structure possibly tracing gas that has been ejected from the galactic nucleus, and (c) mapping large-scale magnetic fields in a sample of star-forming clouds to study the relationship between the elongated shapes of these clouds and their magnetic fields. (AO-376-O; NSF/OPP 01-30389)

ACBAR: Arcminute cosmology bolometer array receiver.
William L. Holzapfel, University of California-Berkeley.

Advances in detector technology are enabling a revolution in cosmology. Arrays of bolometric detectors on the ground have recently been used to image large regions of the cosmic microwave background (CMB) sky from balloons and are detecting luminous dusty galaxies at high redshift. The arcminute cosmology bolometer array receiver (ACBAR) is a 16-element, 250-micro-Kelvin detector system that was deployed at the South Pole in November 2000 and is designed to be used with the Viper telescope there. ACBAR will image the sky in four bands and thus fill an important niche in angular-scale and frequency coverage between existing millimeter-wave, balloon-borne, and ground-based instruments. These four frequency bands were chosen to take full advantage of the excellent millimeter (mm) and submillimeter atmospheric windows available for observations from the South Pole.

ACBAR is designed to probe the Universe in two distinct ways: First, the measurement of small angular-scale structure in the CMB will complement the large angular scales probed by various satellites and balloon-borne instruments, leading to improved constraints on cosmological models. Second, the imaging and discovery of galaxy clusters with the Sunyaev-Zel'dovich Effect (SZE) will provide a wealth of new cosmological information. ACBAR's broad frequency and angular-scale coverage enable enormous leaps forward in both of these directions. The receiver also serves as a test bed for the detector and optics technology that will eventually fly on the European Space Agency's Planck satellite in 2007.

With this combination of sensitive detectors, high-angular resolution, and broad frequency coverage, ACBAR will be used to advance cosmology research on several fronts. Observations of the CMB provide a glimpse of the Universe at the time when it was only about 300,000 years old. Also, only recently have technological advances made observations of the SZE possible. To separate the thermal and kinematic components of the SZE, observations must be made at several mm-wavelength frequencies. Other experiments are producing detections of the SZE in x-ray-discovered distant clusters. ACBAR will significantly advance these efforts.

This second season of observation will see the analysis and publishing of the results of two previous years of observation. (AO-378-O; NSF/OPP 00-91840)

Wide-field imaging spectroscopy in the submillimeter: Deploying SPIFI on the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
Gordon Stacey, Cornell University.

SPIFI (the South Pole imaging Fabry-Perot interferometer) is the first direct detection imaging spectrometer for use in the submillimeter band and was designed for use on the 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) at the South Pole in the far-infrared and submillimeter windows. After having developed and extensively field-tested SPIFI, our primary scientific goals are to

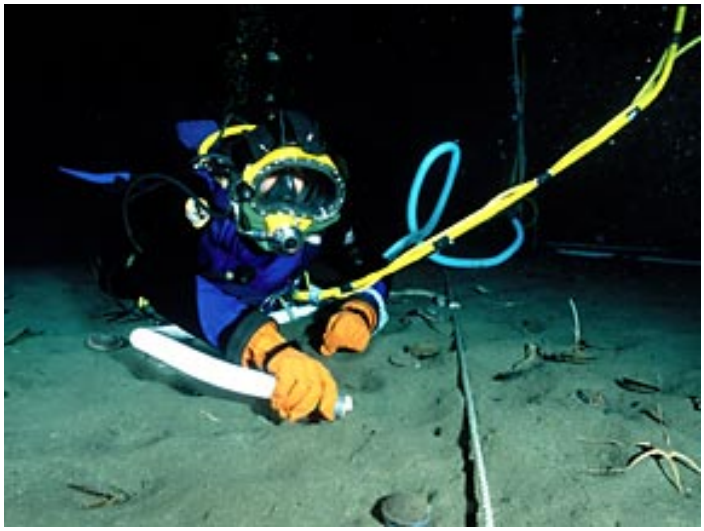
- image the inner regions of the galaxy, in particular submillimeter lines that characterize excitation conditions in the Central Molecular Zone (CMZ), and trace the dynamics of the gas. Questions to be answered are, among others, Can we trace neutral gas flowing through the CMZ? Are there shocks from cloud-cloud collisions in this flow? What is the connection between the CMZ molecular clouds and the circumnuclear ring?

- map the Large Magellanic Cloud and Small Magellanic Cloud in these lines. The low metalicity environment in these dwarf galaxies may mimic that of protogalaxies, so that investigating the interaction between star formation and the interstellar matter in these galaxies is key to understanding the star formation process in the early Universe.

- characterize and map the physical conditions of the interstellar matter in nearby galaxies. These data are unique and will be key to understanding the relationships between density waves, bar potentials, and galaxy-wide star formation.

These projects can be undertaken only with the high sensitivity and mapping capabilities of the SPIFI AST/RO combination. SPIFI is much more sensitive than the best heterodyne receivers, which do not have the sensitivity, or (often) the bandwidth, to detect the broad, weak lines from galaxies, or the spatial multiplexing capability necessary for wide-field mapping projects. We plan to gradually upgrade SPIFI by a factor of 10. We will also make modest optical and cryogenic modifications to SPIFI to improve it in ways important to successful polar operations. The result will be better spatial resolution, with a wider field of view, and a large improvement in system sensitivity. Moreover, the new cryogenic system will require servicing only every 5 days instead of the current 40 hours. This is helpful for outdoor polar operations. This new system also reduces helium consumption (by a factor of 2) and therefore reduces cost. (AO-377-O; NSF/OPP 00-94605)

BIOLOGY AND MEDICINE



Diver Phil Forte vacuums the sea floor of McMurdo Sound for samples of foraminifera, a single-celled creature. Typically, "forams," as they are called, carpet deep-sea floors, but they also emerge in the shallow waters of Antarctica, making them available for study. *(NSF/USAP photo by Steve Alexander)*

Antarctica is a place like no other; as an intriguing habitat, it is a scientist's dream. It is a land where water is scarce-truly a desert-despite having more than two-thirds of the world's freshwater supply trapped in ice. Though it borders the world's major oceans, the Southern Ocean system is unique in the world, a sea where average temperatures do not reach 2°C in summer, where even the water is so unique that it can be identified thousands of kilometers away in currents that originated here. As the Earth, tilted on its rotational axis, makes its elliptical journey around the Sun each year, the Sun "sets" in April, not to be seen again until September. And the ice-an unimaginable, incomparable vastness of ice-appears in a dozen different varieties, at times and in places several thousand meters thick; there are two major ice sheets that change dynamically all the time. (The eastern sheet is larger than most countries.)

Adaptations and behavior developed in response to these extreme conditions provide insight into the intricacies, as well as the fundamental processes, of evolution. These extremes have also driven the development of ecosystems simple enough to reveal wonderfully clear pieces of the web of life on Earth.

The Biology and Medicine program funds research to improve understanding of antarctic ecosystems and life forms-their physiology, genetics, behavior, adaptations, and relationships. Projects range across all organizational levels, from the molecule, gene, cell, and organism to relationships within communities and ecosystems, to the level of global processes and the biosphere. This is another area of inquiry where scientific goals and benefits extend far beyond learning (in this field, about flora and fauna) in the high latitudes. Support is focused on the following areas:

- **Marine ecosystem dynamics:** Among the research topics are understanding the natural variability of marine ecosystems, correlating the structure and function of the marginal ice-zone ecosystem with oceanic and atmospheric processes, exploring the sources of nutrition and their influence on prey and on primary production, and the role of marine phytoplankton in carbon-dioxide cycling.

- **Terrestrial and limnetic ecosystems:** Organisms in ice-free areas and in perennially ice-covered lakes

show remarkable adaptations to extreme environments. Relatively few species thrive here, which facilitates the study of ecosystem dynamics and the interpretation of experiments, although much more remains to be learned about adaptive mechanisms and evolutionary processes.

- **Population biology and physiological ecology:** At the next level, looking at relationships among organisms, studies have focused on the variability and dynamics of populations of krill and other zooplankton. Ecological relationships among and between fish species, marine mammals, and birds have also been the object of much research, with many issues still to be further explored. Advances in genetic testing now permit scientists to establish relationships that were previously unverifiable between individuals and species in the wild. As organized programs of antarctic science enter their fifth decade (some have been in existence even longer), data sets and ongoing observations are elucidating manmade as well as natural changes.

- **Adaptation:** Antarctic extremes present a fundamental research opportunity; topics include low-temperature photosynthesis and respiration; enzymatic adaptations, and adaptive physiology, such as the development in fish of antifreeze compounds and modifications to the circulatory system in seals. There is also continuing interest in the response of organisms to increased ultraviolet-B radiation from the ozone hole (as well as its impact on them). Here, too, new molecular DNA advances have had a profound impact on the types of studies that can be mounted.

- **Human behavior and medical research:** Antarctica's extreme climate and terrain impose a quite spartan and unconventional existence on scientists and others who live and work there. As people are subjected to social, psychological, and physiological stresses (exacerbated during the winter isolation), opportunities for research arise. Studies focus on epidemiology, thermal regulation, immune system function, individual behavior, and group dynamics.

Function and chemical nature of ice-active substances associated with sea-ice diatoms.
James Raymond, University of Nevada-Las Vegas.

Sea-ice diatoms (a class of algae) are plentiful in the ice platelet layer and congelation ice in McMurdo Sound. Previous work suggests that these diatoms produce extracellular ice-active substances (IASs), molecules with large molecular weights that appear to be glycoproteins. The IASs seem to be associated with each species of sea-ice diatom. Because similar molecules have not been found in temperate-water diatoms, they apparently have a function related to cold or icy environments.

The IASs represent a novel type of ice-binding molecule that is distinct from the antifreeze proteins and glycoproteins found in some fish species. The IASs also do not lower the freezing point as fish antifreezes do, so their function is unclear. One possibility is that they help preserve cells when they are in the frozen state, so that when they thaw, a higher percentage will survive.

We will examine several questions about the function and chemical nature of these unusual molecules:

- The IASs appear to have cryoprotective properties. To explore this possibility, we will assess the IASs' ability to prevent freeze-thaw damage in whole cells. Survival will be assayed by uptake of carbon-14-labeled bicarbonate. We will also investigate the ability of the IASs to inhibit the recrystallization of ice, which is a common measure of antifreeze activity in plant studies.

- The IASs are known to bind to ice crystals. To better understand the mechanism involved, we will conduct additional studies to determine the specific crystal faces to which they bind.

- We will try to better characterize the chemical nature of the carbohydrate and protein components found in the IASs by means of mass spectrometry, amino acid sequencing, and other techniques.

- We will attempt to raise antibodies against the IASs, since these will have several uses in determining the origin, seasonality, relatedness, and possibly the function of these molecules.

- We will attempt to harvest sea ice from the Polar Sea as a new method for obtaining IASs. (BO-001-M; NSF/OPP 00-88000)

Antifreeze protein in antarctic fishes: Ecological and organismal physiology, structure-function, genetics, and evolution.
Arthur DeVries, and Chi-Hing Cheng, University of Illinois.

Despite temperatures that can dip below 0°C, antarctic waters provide a life-sustaining environment for a number of fish species. How are they able to take the most frigid waters on Earth through their gills without freezing? A primary reason is the so-called antifreeze proteins, an adaptation found in a number of polar and subpolar species. These biological molecules have an effect similar to that of antifreeze in a mechanical engine. The Southern Ocean provides the ideal laboratory and molecular biology the ideal probe to study this phenomenon. As the world's coldest marine environment, the near-shore waters of Antarctica, replete with ice crystals, hover just above the freezing point of sea water.

We are studying the physiology of fish and larvae from these waters to see how ice grows in biological tissues-a crystallization process called nucleation-and how antifreeze glycoproteins inhibit it. Evolving the antifreeze function has enabled antarctic notothenioids to colonize their frigid habitats very successfully. We are mounting comprehensive multidisciplinary analyses of this adaptation at the level of the gene as well as the protein.

Specifically, we will

- examine the structure of antifreeze proteins,

- refine the molecular model of how these proteins adsorb ice and inhibit the growth of ice crystals,

- study the physiological parameters governing the natural growth of ice crystals,

- pinpoint the chromosomal locus of the gene family and its protease progenitor gene,

- sketch its evolutionary history by calibrating the rate of notothenioid nuclear protein coding sequences, and

- focus on when these antifreeze glycoproteins develop during embryogenesis and early larval stages. (BO-005-M; NSF/OPP 99-09841)

Energetics of protein metabolism during development of antarctic echinoderms.
Donal T. Manahan and Robert Maxson, University of Southern California.

Larval forms are dominant in the life history strategies of invertebrates in marine environments. In Antarctica, energy budget calculations have shown that larval stages of echinoderms (radially symmetric marine animals like starfish and sea urchins) have the capacity to survive for years without food. This has led to the speculation that

mechanisms of energy metabolism are more efficient in these larval forms and that this enhanced efficiency might be unique to life in extreme cold.

Embryos and larvae of an antarctic sea urchin have high rates of protein synthesis while maintaining low rates of metabolism. The cost of protein synthesis in this antarctic sea urchin is 1/25th that reported for other animals. This is the lowest cost (highest efficiency) for protein synthesis ever reported and has important implications for the physiology of animal growth and development in cold environments. We intend to investigate this unique biochemical efficiency in detail.

Our experimental plan has three major objectives:

- to test the generality of the low cost of protein synthesis in antarctic sea urchin larvae by measuring metabolism and protein synthesis during development of other antarctic echinoderm species,
- to directly test the hypothesis that a high rate of protein synthesis with low metabolic cost means that growth efficiencies will be high in such organisms,
- to explain in specific molecular terms the unique high efficiency of protein synthesis in antarctic sea urchin embryos by studying each of the component processes of protein synthesis.

We will also supplement these measurements with measurements based on selected individual proteins. At the subcellular level, rates of ATP consumption during protein synthesis will be measured in cell-free translation systems of sea urchin embryos. The combination of these quantitative analyses will enable us to pinpoint those aspects of protein metabolism that result in such extremely high-energy efficiencies.

Understanding metabolic efficiency in polar organisms will help resolve questions about temperature compensation and adaptations to food limitation in polar regions. Our approach will emphasize the cellular and subcellular levels of biological analysis in order to understand the relationship between development, growth, metabolic rate, and rates and costs of protein synthesis in these organisms. We will test the hypothesis that there is a "new" biochemistry for protein synthesis in these organisms. (BO-006-O; NSF/OPP 01-30398)

Use of long-term database and molecular genetic techniques to examine the behavioral ecology and dynamics of the Weddell seal (*Leptonychotes weddellii*) population.
Robert A. Garrott and Jay Rotella, Montana State University-Bozeman, and Donald Siniff, University of Minnesota.

The study of the Erebus Bay Weddell seal population in eastern McMurdo Sound was initiated in 1968 and represents one of the longest intensive field investigations of a long-lived mammal in existence. Some 15,636 animals have been tagged, with 144,927 resighting records in the database.

We intend to build on this foundation with two lines of investigation that combine the long-term database with new field initiatives. We will maintain the continuity of the demographic data by annually marking all pups born, replace lost or broken tags, and perform multiple mark-recapture censuses. The new data will be combined with the existing database, and a complex series of demographic analyses will be performed. These analyses will allow us to test hypotheses about population regulation, as well as temporal and spatial patterns of variation in vital rates among colonies within the population.

A sample of adult female seals and pups will be weighed, and body morphometrics will be obtained using digital photography combined with image analysis software. Regression equations will be developed from these data to predict body mass. At each major colony within Erebus Bay, these regression equations will be used to estimate annually the parturition and weaning mass of a large sample of adult female seals and their associated pups. We

will also employ satellite imagery to track sea-ice extent in McMurdo Sound. The extent of sea ice affects regional primary productivity, which may increase marine resources, thereby having a positive effect on foraging efficiency and leading to increased body mass. These data, combined with the large proportion of known-aged seals in the current study population (more than 60%), will allow us to develop a powerful database to test specific hypotheses.

Learning about the mechanisms that limit and/or regulate Weddell seal populations and the specific biophysical links between climate, oceans, ice, and antarctic food webs can make an important contribution toward understanding pinniped population dynamics, as well as add to the understanding of population, community, and ecosystem patterns and processes. Continuation of this long-term study may also contribute toward understanding the possible detrimental impacts of human activities such as global climate warming and the commercial exploitation of antarctic marine resources. And, finally, the study can contribute significantly to the development and testing of new research and analytical methodologies that will almost certainly have other applications. (BO-009-M; NSF/OPP 97-25820)

Community dynamics in a polar ecosystem: Benthic recovery from a large-scale organic enrichment in the Antarctic.
Stacey Kim, San Jose State University.

In 2002-2003, McMurdo Station, the U.S. research station that houses over 1,100 people during the summer season, is completing construction of a sewage treatment plant that will be online in 2003. The existing outfall is a large source of organic enrichment (135,150 liters per day of untreated sewage); the new plant will output a small fraction of this amount.

The organically enriched outfall area and surrounding unperturbed areas have been well described. Detailed community descriptions of the epi- and infaunal community at the outfall location before effluent release are available and were collected over a long period (1988 to 1998), which minimizes the interannual variability.

We will examine community responses in a polar soft-bottom subtidal system to test the generality of an already elucidated paradigm. Community recovery rates from iceberg scours and anchor ice have been described. We hypothesize that recovery rates following cessation of organic input will be on the same scale as benthic community recovery from seasonal ice-mediated disturbances and as recovery rates in temperate systems. We will build on a 10-year time series that follows benthic community degradation resulting from a sewage outfall. Sampling will span the implementation of sewage treatment. To test the generality of recovery patterns, the data will be incorporated in a meta-analysis of community recovery from organic disturbance in a variety of habitats. Experimental manipulations will compare the roles of burial and patch size. In addition, efforts will be directed at microbial biochemical response and diversity, in tandem with the recovery of the infaunal community.

The knowledge gained from this research can be applied to any high-organic loading in polar habitats. Significant anthropogenic inputs in high latitudes include pulp mills and increases in human occupation and visitation (gray water dumping from boats). Natural sources, including woody debris in river outputs and carcass-falls from the productive surface waters above, also present significant carbon input. In the McMurdo area, marine mammals and large fish are abundant and add fecal material to the system. Supply vessels dock in Winter Quarter's Bay, and the number of tourist cruises is increasing. By using an integrated approach to evaluate the recovery of the microbial, infaunal, and epifaunal assemblages after a massive, 10-year carbon-loading perturbation, this study will further the understanding of anthropogenic impacts in polar environments. (BO-010-O; NSF/OPP 01-26319)

Hunting behavior and energetics of free-ranging Weddell seals.
Randall Davis and Markus Horning, Texas A&M.

Weddell seals (*Leptonychotes weddellii*) are the apex predators in the antarctic marine ecosystem, in large part because of behavioral and energetic adaptations that enable them to forage in the cold, dark, fast-ice environment. Earlier work pioneered the use of an animal-borne video system/data logger to record the behavior,

physiology, and locomotor performance of marine mammals at depth. For the first time, we witnessed seal hunting strategies and predator-prey interactions and were able to make corresponding estimates of diving metabolism. Here we follow up on those results and hope to provide insight into the foraging tactics of marine mammals and contribute to the fields of physiology (diving and energetics) and ecology (foraging theory and behavioral ecology).

By using isolated ice holes, we formerly preserved the seals' ability to choose the depth and duration of a dive, but left them no alternative but to return to a single place to breathe, thus limiting their range. We did not permit them to haul out of the water or interact with other seals on the ice, and thus they may have been exposed to fewer prey than when foraging naturally. Now we want to remove those constraints and focus on the behavior and energetics of completely free-ranging seals. Although the "constrained" study demonstrated important new principles in Weddell seal foraging and has increased our understanding of diving behavior and swimming performance, we believe that it is now essential to determine whether those principles apply to unconstrained animals.

To answer this question, we will test hypotheses related to the general foraging strategy, foraging location, searching mode, detection of prey, locomotor performance, cost of diving, and foraging efficiency of free-ranging Weddell seals. In addition, we will examine locomotor performance and behavior during diving to estimate the costs associated with hunting and the benefits gained from it (the type and frequency of prey captures).

The study will continue to employ a multidisciplinary team of scientists with highly skilled technical support. The results will advance our understanding of the foraging ecology of Weddell seals and create a basis for similar research on other species of marine mammals that are more difficult to study in the open ocean. (BO-017-O; NSF/OPP 99-09422)

Ontogeny of aerobic capacity, lipid metabolism, and elevated myoglobin concentrations in the skeletal muscles of the Weddell seal (*Leptonychotes weddellii*).
Shane B. Kanatous, University of Texas, and Rhonda Bassel-Duby, University of Texas Southwest Medical Center.

What is the temporal development of aerobic capacity, lipid metabolism, and oxygen stores in the skeletal muscles of young Weddell seals, and which aspects of the cellular environment are important in the genetic regulation of myoglobin expression during maturation? We will address this broad question during a 2-year study that will collaborate with an ongoing study of the diving and hunting behavior of free-ranging adult and subadult Weddell seals (see project BO-017-O). Results from our previous collaboration characterized the enzymatic, ultrastructural, and vascular adaptations for diving that occur in the skeletal muscles of adult Weddell seals. This study builds on those results to investigate the ontogeny of these adaptations and the genetic control of their development.

Our first objective is to characterize the ontogenetic changes in aerobic capacity, lipid metabolism, fiber type, and myoglobin concentration and distribution using enzymatic, immunohistochemical, and myoglobin assays in newborn, newly weaned, subadult, and adult seals. Our second objective is to determine the molecular controls for changes in the concentration and distribution of myoglobin in skeletal muscles during maturation. Through subtractive hybridization and subsequent analysis, we will determine the differences in mRNA populations in the swimming muscles of the different age classes of Weddell seals. These techniques will allow us to identify the proteins and transcription factors that influence ontogenetic changes in myoglobin concentration. The results will increase our understanding of both the ontogeny and molecular mechanisms by which young seals acquire the physiological adaptations they need to become competent divers and marine predators.

In addition, this study will advance our knowledge of the molecular regulation of myoglobin in skeletal muscle, which has broader applications for human medicine. Our collaboration with research on the diving and hunting behavior of Weddell seals will enhance the results of both studies, minimize the number of adult animals handled, share personnel, and reduce the need for additional logistical support. (BO-018-O; NSF/OPP 01-25475)

Yeasts in the antarctic dry valleys: Biological role, distribution, and evolution.
Laurie B. Connell, University of Maine; and Russell Rodriguez, University of Washington.

The soil community of the antarctic polar desert comprises few endemic species of bacteria, fungi, and invertebrates. Both filamentous and single-cell fungi have been isolated from a diversity of antarctic soil types, but only yeasts appear to be endemic to the polar desert soils. Although their ecological role in antarctic soils is undefined, yeasts may be the principal taxa synthesizing the sterols required by soil invertebrates. In addition, yeasts may be involved in accumulating and mobilizing growth-limiting nutrients such as phosphorus into the polar desert food web. Although yeasts have been well described in agricultural and industrial systems, little is known about their ecological role.

This multidisciplinary, collaborative research will characterize the role(s) soil yeasts play in the McMurdo Dry Valley ecosystem in order to better understand polar deserts and other extreme environments, as well as provide a foundation for incorporating yeasts into biogeochemical models of temperate environments. Soil microbiota mediate most processes such as decomposition, soil respiration, uptake and fixation of micro- and macronutrients, and detoxification of heavy metals and serve as major global carbon sinks. The complexity of soil communities in temperate regions poses difficulties in studying the relationships between biotic and abiotic parameters, and the factors controlling populations of soil microbiota remain poorly understood. The extreme climate and relatively simple community structure of the continental antarctic desert lend themselves to such studies.

We will first correlate the abundance and distribution of yeasts in polar desert soils with physical and chemical soil properties. Several physiological parameters will be explored in vitro to develop a basis for understanding the functional role(s) these organisms might have. Sterols synthesized by McMurdo Dry Valley soil yeasts, as well as their ability to survive multiple freeze-thaw cycles, will be characterized. The capacity of indigenous antarctic yeasts to use, compete for, and store phosphorus will be ascertained. The evolution of dry valley yeasts will be addressed by determining intra- and intervalley relatedness patterns based on DNA sequence.

Both soil samples and extracted DNA will be shared with other interested laboratories. Moreover, students from middle school (Biolab Inc.) through college (University of Maine) will be given the opportunity to collaborate on this project, as well as to develop their own projects. (BO-019-O; NSF/OPP 01-25611)

Participation in the Italian Ross Sea expedition.
Diane K. Stoecker, University of Maryland.

This project is an outgrowth of previous collaboration between Horn Point Laboratory, University of Maryland Center for Environmental Science, and the University of Trieste and the Laboratory for Marine Biology, Trieste, Italy. In December 2002, we will sail from New Zealand as part of the Italian expedition to the Ross Sea and land at the Italian station at Terra Nova in early February 2003.

Previous collaboration has involved the grazing dynamics and physiology of plankton from temperate coastal systems in the Adriatic Sea and the Chesapeake Bay. Techniques that have been recently developed to investigate the autecology (the ecology of individual organisms or individual species) and population dynamics of temperate, coastal, bloom-forming algae will be applied to polar protists from the Ross Sea. We will compare the role of microzooplankton grazing in bloom dynamics in temperate and polar systems, determine whether polar microplankton have ectocellular protease activity, and obtain samples of the photosynthetic ciliate, *Mesodinium rubrum*, and its algal "prey" from the Ross Sea for molecular analysis.

Microzooplankton (primarily dinoflagellate and ciliate) grazing is important in regulating the growth of many bloom-forming phytoplankton in temperate estuaries. We know that blooms can initiate only during windows of opportunity when grazing pressure by microzooplankton is low, but little is known about the specific grazing of microzooplankton on bloom species in polar seas.

We also intend to determine whether polar phytoplankton have cell surface enzymes that could be involved in the use of dissolved organics. Temperate dinoflagellates have considerable leucine amino peptidase activity and thus may be able to use polypeptides and proteins as a source of carbon or nitrogen. The research undertaken on this collaborative cruise will advance comparative studies of temperate and polar marine ecosystems and the physiological ecology of temperate and polar protists. (BO-020-E; NSF/OPP 02-30775)

Collaborative research: The chemical ecology of shallow-water marine macroalgae and invertebrates on the Antarctic Peninsula.
Charles D. Amsler and James B. McClintock, University of Alabama-Birmingham, and Bill J. Baker, University of South Florida

Many organisms are not mobile and so cannot escape from predators. One way they can keep from being eaten is to make themselves unappetizing by producing defensive chemicals known as secondary metabolites. However, the energy and other resources that go into making these compounds could instead have gone into growth or reproduction. We are studying the evolution of these tradeoffs and hope to understand ways that organisms maximize the usefulness of their investments in defensive chemistry.

For marine plants, the physical environment of Antarctica is very different from most other places in the world's oceans because nutrients are plentiful but light is often limited. So the "currency" that is used to "pay" for defense, growth, and reproduction is different than for plants in most other marine communities. This allows us to test theories about the costs and benefits of defense in ways not possible elsewhere in the world.

For marine animals, Antarctica is unique in that predation by sea stars is much more important than in other marine communities. Sea stars feed by extending their stomachs from their mouths and digesting prey outside their bodies. We predict that this should lead to a much higher investment in defensive metabolites in the outer layers of the prey. One of the main goals for our 2002-2003 season will be to test the hypothesis that sponges (an important component of these communities) will maximize their investment in chemical defense by having the highest levels of defensive secondary metabolites in their outermost layers.

This research should also advance our general understanding of the evolution of chemical defenses. We hope to elucidate the nature and role of bioactive agents in the specific ecology of the antarctic marine benthos (that is, organisms living at the bottom of marine environments). (BO-022-O; NSF/OPP 01-25181 and NSF/OPP 01-25152)

Food-web structure across a large-scale ocean productivity gradient: Top predator assemblages in the southern Indian Ocean.
George L. Hunt, University of California-Irvine.

During an Océan Indien Service d'Observation cruise, we will test the hypothesis that the dispersion and community of top predators vary with large-scale differences in physical structure and ocean productivity by conducting an interdisciplinary survey of marine bird and mammal use of distinct domains in the southern Indian Ocean. Our French colleagues will sample physical characteristics of the ocean and ocean productivity while we survey top predator distributions across a 35º latitudinal gradient from subtropical to subantarctic waters.

We will address the primary hypothesis that top predator assemblages are structured by spatial gradients in hydrographic properties and ocean productivity patterns known to influence the distribution and patchiness of their zooplankton, fish, and squid prey. We hypothesize that the overall abundance of marine top predators within a specific domain is largely determined by ocean productivity. Further, we hypothesize that the energetic costs of foraging determine which types of marine top predators inhabit specific domains. Species with high foraging costs must exploit dense prey aggregations within highly productive areas. Conversely, taxa with low foraging costs are able to inhabit areas of low productivity, where they exploit more dispersed prey.

To test these hypotheses, we will quantify the spatial association of top predator assemblages with specific water masses and the aggregate response of top predators at hydrographic and bathymetric domains. Because top predators respond to oceanographic variability at multiple scales of time and space, we will assess their responses to habitat variability at two specific scales. At the mega-macro scale [thousands of kilometers (km)], we will characterize faunal associations with specific water masses and ocean productivity domains. At the coarse scale (tens of km), we will quantify top predator aggregations at frontal systems and continental shelf margins.

We will employ a variety of analytical methods, including compositional analysis of coarse-scale habitat preferences, generalized additive models, recurrent group analysis, ordination of hydrographic data and top predator assemblages, and measurement of top predator aggregation using Lloyd's index of dispersion and autocorrelation statistics.

More specifically, we will study how overall top predator abundance and the distributions of distinct assemblages and feeding guilds change across spatial gradients in physical and biological properties. This interdisciplinary perspective will enhance our understanding of the way physical and biological processes structure pelagic communities in the southern Indian Ocean. (BO-025-O; NSF/OPP 02-34570)

Cultural emergence and health in Antarctica.
Timothy Dye, and Nancy Chin, University of Rochester.

The emergence of a long-term population in space will, in many ways, parallel the emergence of a sustained population in Antarctica, where development has expanded beyond the initial population of scientific and military personnel and now includes support staff and construction personnel. Experts speculate that a similar mix of residents may emerge as space populations develop. Such organizational and cultural merging in restricted environments undoubtedly creates new cultural landscapes (ethnoscapes) that could influence health and health behavior. Because of the extreme environmental circumstances, health risks and health care are particularly important. The study of cultural emergence in Antarctica as an analog to space could prove useful in the development of models of health and health behavior in an isolated confined environment (ICE) and could help planners better structure these environments to reduce health risks and identify factors that predispose people to those risks.

We aim to

- model the emergence of cultural stages in ICE ethnoscapes as experienced by both short- and long-term populations;
- identify those elements of ICE ethnoscapes that are specific to an individual season and those that are repeated;
- relate how the temporal and content stages of ICE ethnoscapes interact with risk, behavior, and injury; and
- demonstrate the utility of electronic and distance-based assisted ethnography in the conduct of social research in ICE environments of Antarctica, and possibly in space.

We will begin with key informant interviews and focus groups conducted throughout the United States with people who have spent at least one season on the ice within the past 3 years. The purpose is to elucidate the behaviors, risks, and health events that face residents, particularly in the emergence of ethnoscapes. The next phase has us residing in Antarctica for an extended period and conducting onsite participant observation and interviews at two different sites. This phase will include the Self-Disclosure Technique (SDT), an anthropological

method for identifying the conceptual structure of a cultural event. SDT will be used to describe cultural dynamics in occupational, recreational, spiritual, and other group activities. Fieldwork will involve both short- and long-term residence. The data will be processed, and models will be tested for validity with informants on the ice.

This research could contribute to the development of screening procedures for long-term residence in ICEs and context-sensitive explanatory models of culture and injury risk, as well as illustrate the utility of distance-based ethnography. (BO-027-O; NSF/OPP 01-25893)

Geographic structure of Adélie penguin (*Pygoscelis adeliae*) populations: Demography of population expansion.
David G. Ainley, H.T. Harvey and Associates; Nadav Nur and Grant Ballard, Point Reyes Bird Observatory; and Katie Dugger, Southern Illinois University.

We are investigating the mechanisms responsible for the geographic structuring, the founding of new colonies, and the recent population expansion of the Adélie penguins of Ross and Beaufort Islands. Similar expansion has been occurring throughout the Ross Sea, where 30 percent of the world population of this species resides, and is in some way related to ameliorating climate. Thus far we have been examining

- the relative importance of resources that constrain colony growth (the amount of nesting habitat versus access to food);
- aspects of natural history that might be affected by exploitative or interference competition among neighboring colonies (breeding success and foraging effort);
- climatic factors that influence the latter, especially extent and concentration of sea ice; and
- behavioral mechanisms that influence colony growth as a function of initial size and location, emigration, and immigration.

None of the colonies is nesting space limited, and we have shown how sea-ice extent and concentration affect diet, foraging effort, and winter survival. In addition, large colonies affect the foraging patterns of smaller ones within range and, perhaps, ultimately their size. The rate and direction of emigration also appear to be constrained by sea-ice conditions, with reasonable concentrations of ice favoring growth of smaller colonies where foraging competition is minimal. Yet to be determined is the demographic mechanism of colony growth (or decline). Reproductive success does not appear to be important, however.

We will use seven cohorts of marked penguins from each colony to assess juvenile survival, recruitment age, and age-specific fecundity and subsequent survival. These data will be compared with another demographic study, the only one for this species, conducted at Cape Crozier during the 1960s and 1970s when populations were declining.

Information will be related to sea ice as quantified by satellite images. Global climate is changing fastest in the polar regions. The Adélie penguin is tied to sea ice, a primary factor in rapid polar climate change (less sea ice, less reflection of solar energy). The extreme sensitivity of these penguins to climate change has been often noted. Understanding the demographic mechanisms behind this sensitivity will contribute greatly to knowledge of the effects of climate change on antarctic marine organisms. (BO-031-O; NSF/OPP 01-25608)

Investigations of abandoned penguin colonies in Antarctica.
Steven Emslie, University of North Carolina.

Climate change is assumed to be a pivotal factor in the success of many species. This project will investigate the history of Adélie penguins in late Holocene Antarctica. By locating and examining the fossil remains of former colonies, scientists hope to develop a model of when they thrived and when colonies were abandoned-and thus their success-relative to climate change. This model could inform current science on the relationship between climate and population dynamics.

Our study will integrate data from the ecological, geological, and paleobiological records with satellite-imagery analyses. The climate factor will be inferred by data contemporaneous with the fossil evidence, in particular the extent of the sea ice and marine productivity. The population factor will be developed through field and laboratory investigations of abandoned colonies along coastal Antarctica.

Researchers will first collect surface and subsurface bones, feathers, and eggshell fragments preserved at these sites; later, in the laboratory, scientists can reconstruct the occupation history of each abandoned colony through standard and radiocarbon analyses. Sediments from each site will be sifted to recover organic remains (such as squid beaks and fish otoliths) believed to be the staples of the penguin diet. Statistical analysis of such indicators can trace the changing size of the colony at specific prehistoric times, and thus consumption of prey becomes a proxy for population success. This timeline can then be matched to past episodes of climate change, which are well documented for the late Pleistocene and Holocene in ice-core and marine sediment records.

We expect these ancient responses by penguins to climate change (as indicated by the paleoecological record) to parallel those observed in Antarctica today, where regional warming has been documented over the past 20 to 50 years. Ultimately, we will be able to test the hypothesis that Adélie penguins have been responding to climate change in a predictable manner for decades and centuries and that those responses can be anticipated, relative to fluctuations in the extent of sea ice and marine productivity. (BO-034-O; NSF/OPP 99-09274)

Cold temperature as an evolutionary shaping force in the physiology of the antarctic fishes.
Bruce D. Sidell, University of Maine.

Notothenioid fishes have been evolving for 10 to 14 million years at a nearly constant body temperature of ~0ºC. Many unusual characteristics of these fishes are adaptations to life at cold body temperatures or physiological or biochemical features permitted by life at cold body temperatures but otherwise deleterious. Our three major objectives will entail a combination of shipboard collection of fishes and experimentation at Palmer Station, with more extensive and sophisticated laboratory analyses on samples in the United States.

Our first aim is to identify the amino acid substitutions in the fatty acid-binding pocket of fatty acyl coenzyme A synthetase (FACS) from antarctic fishes. Fatty acids are a major source of energy in these fishes, and FACS is essential to their metabolism. Site-directed mutagenesis will be used to produce modified antarctic fish FACS in which specific amino acids have been mutated to those of consensus sequences from warmer-bodied vertebrate animals. These experiments may permit us to determine the specific substitutions that explain both substrate specificity and preservation of catalytic rate of notothenioid FACS at cold temperatures.

Our second goal is to produce a rigorous biochemical and biophysical characterization of an intracellular binding protein, parvalbumin, from antarctic fishes. Parvalbumin plays a pivotal role in facilitating the relaxation of fast-contracting muscles and is a likely site of strong selective pressure. Preliminary data strongly indicate that in antarctic fishes, the protein has been modified to function at cold temperatures. Full-length clones for antarctic fish parvalbumin(s) will be obtained. In combination with already available information, these data will yield insight into their functioning at very cold body temperatures.

Our third goal is to conduct a broad survey of the pattern of cardiac myoglobin (Mb) expression in the Notothenioidei. Previous work has indicated a variable pattern of presence or absence of Mb in the hearts of icefishes, probably due to the unusually low niche competition in the Southern Ocean. It is likely that similar loss of cardiac Mb will be observed in other notothenioid taxa. We will survey as many notothenioid species as possible and will use molecular biological techniques to determine the mechanism(s) responsible for loss of Mb

expression. (BO-036-O; NSF/OPP 01-25890)

Structure, function, and expression of tubulins, globins, and microtubule-dependent motors from cold-adapted antarctic fishes.
H. William Detrich III, Northeastern University.

As the Southern Ocean cooled during the past 25 million years, the fishes of antarctic coastal waters evolved biochemical and physiological adaptations that maintain their essential cellular processes. The long-range goals of our research are to determine, at the molecular level, the adaptations that enhance the assembly of microtubules (thin tubes made of protein and used to make structures involved in cellular movement), the function of kinesin motors, and the expression of globin and tubulin genes. Our specific objectives are

- to determine the primary sequence changes and posttranslational modifications that contribute to the efficient polymerization of antarctic fish tubulins (globular proteins) at low temperatures;
- to determine the primary sequence changes and posttranslational modifications that contribute to the efficient polymerization of antarctic fish tubulins (globular proteins) at low temperatures;
- to characterize the structure, organization, and promoter-driven expression of globin and tubulin genes from an antarctic rockcod (*Notothenia coriiceps*) and a temperate congener (*N. angustata*).

Brain tubulins from antarctic fishes differ from those of temperate and warm-blooded vertebrates both in unusual primary sequence substitutions and in posttranslational C-terminal glutamylation. Potential adaptations of antarctic fish tubulins will be tested directly by production of wild-type and site-directed tubulin mutants for functional laboratory analysis. We will determine the capacity of fish tubulins to form "cold-stable" microtubules, and we will test the role of the carboxy-terminal charge status of tubulin in cold adaptation of microtubule assembly after enzymatic manipulation.

Three unusual substitutions in the kinesin motor domain of *Chionodraco rastrospinosus* may enhance mechanochemical activity at low temperatures. To test the functional significance of these changes, fish residues will be converted to those found in mammalian brain kinesin. Reciprocal substitutions will be introduced into the framework of the mammalian kinesin motor domain. After production in *Escherichia coli* and purification, the functional performance of the mutant motor domains will be evaluated.

Also, molecular adaptation of gene expression in *N. coriiceps* will be analyzed. Structural features that support efficient expression will be assessed. Comparison with *N. angustata* should help delineate elements of the regions that are important for high-level expression at low temperatures. The functions of possible regulatory elements will be tested by deletion analysis and by specific mutagenesis. Together, these studies should reveal the molecular adaptations of antarctic fishes that maintain efficient cytoskeletal assembly, mechanochemical motor function, and gene expression at low temperatures and advance the molecular understanding of the poikilothermic mode of life. (BO-037-L; NSF/OPP 00-89451)

Investigations on deterioration in the historic huts of the Ross Sea region of Antarctica.
Robert A. Blanchette, University of Minnesota.

During the first two decades of the 20th century-Antarctica's "Heroic Era"-Europeans mounted a handful of expeditions in hopes of reaching (and claiming) the geographical South Pole. Base camps established in the McMurdo Sound region by Scott at Cape Evans and Shackleton at Cape Royds were abandoned once the expeditions were over, leaving behind thousands of artifacts, as well as the huts the explorers built for shelter and storage. Over the intervening 90 years, the extremes of the polar environment have actually protected some of the artifacts from rapid decay, but conservators have recently become concerned about serious degradation of

what is an important historical, archaeological site.

Some of the most exigent threats are as follows:

- Wood in contact with the ground is being destroyed by a specific wood-destroying fungus. Various molds and cellulose-degrading fungi are attacking artifacts made of leather, textiles, and other organic materials.

- Exterior wood is being degraded by nonbiological processes of deterioration as well, including salt, ultraviolet radiation, and wind erosion.

- Chemical damage within the huts is apparent, and the soils on the site are contaminated with aromatic hydrocarbons from petroleum products.

We plan to identify the biological and nonbiological agents responsible for the deterioration, study the mechanisms and progressive sequence of events taking place during the decay processes, test methods to be used to control future deterioration, determine the extent of environmental pollutants in soils at the historic sites, and evaluate chemical spills within the huts. The goal is to provide the scientific data conservators need to help protect these important historic sites for future generations. But the project should also shed light on these unique deterioration processes, as well as augment scientific understanding of the biology of antarctic microorganisms and the biodiversity of microbes present in this unusual environment. (BO-038-O; NSF/OPP 99-09271)

Penguin-krill-ice interactions: The impact of environmental variability on penguin demography.
Wayne Trivelpiece, Southwest Fisheries Science Center, National Oceanic and Atmospheric Administration.

How well organisms thrive in their environment is often revealed by basic ecological relationships. For two decades, data have been collected on several species of penguins, including the Adélie, gentoo, and chinstrap, at Admiralty Bay on King George Island in the Antarctic Peninsula. Looking at some of the basic aspects of the lives of these predators, such as survival and recruitment, population size and breeding success, and diets and foraging ecology, scientists have been able to develop and test key hypotheses about variability in the antarctic marine ecosystem.

To explore these relationships, we will periodically capture adult and juvenile penguins to band, measure, and weigh them, and to collect blood and diet samples for genetic and physiologic studies. During the breeding season, the penguins and the sea ice will be observed by satellite. Another aspect of the population biology of penguins relates to the possible impact of commercial fishing, so this study will provide useful information to the Convention for the Conservation of Antarctic Marine Living Resources, which is the part of the Antarctic Treaty System that focuses on fisheries management. (BO-040-E; NSF/OPP 99-80641)

Seasonal dynamics of giant agglutinated foraminifera.
Samuel Bowser, New York State Department of Health.

Found in all marine environments, foraminifera ("forams") are single-celled, shelled (agglutinated) creatures with a key role in the ocean food web. They may be planktonic (floating in the water) or benthic (living on shells, rock, or seaweed, or in the sand or mud at the bottom of the ocean). Their characteristic habitats and the chemistry of their shells (which reflects the qualities of the local water they live in) make them very useful to scientists as an indicator of when and under what conditions they lived. Antarctica and the Southern Ocean ecology are no exception.

Previous studies have shown that the forams in Explorers Cove in McMurdo Sound consume a wide variety of

prey, ranging from bacteria through a taxonomically diverse group of metazoans, including juvenile invertebrates. These studies have been restricted to specimens collected from October through early December, immediately following the austral winter.

But in the succeeding months of the austral summer, a burst of biological productivity occurs, both under the ice and in the benthos. Lacking studies of this period, we do not know how the forams might be responding to this summer food pulse. Looking at such indices as species composition, densities, size distribution, and others, we plan to document changes in relevant abiotic and biotic factors in the Explorers Cove benthos from austral spring to late summer and to characterize how the agglutinated foram community structure responds. To accomplish these analyses, we will use sediment cores, underwater microscopy, molecular tools, isotope analysis of lipids, and some other newly refined methods.

We expect these combined approaches to elucidate the roles played by larger agglutinated forams in the Explorers Cove benthic food web, especially the ways these roles may change consequent to the summer food pulse. Further, the results of these studies should have wider significance in the ocean sciences because Explorers Cove and its agglutinated foram assemblage are comparable to many bathyal and abyssal deep-sea localities.

To enhance insight into marine processes associated with global climate change, we are also collaborating with investigators from Russia to

- test the universality of meltwater turbidity impacts documented in the Arctic,
- assess changes (by adapting modern biochemical and molecular assays) in the living foraminiferal assemblage in response to glacial meltwater, and
- explore ways of revealing the imprint of glacial proximity in the antarctic fossil record. (BO-043-O; NSF/OPP 00-03639)

Interannual variability in the antarctic Ross Sea (IVARS): Nutrients and season production.
Walker Smith, Virginia Institute of Marine Sciences.

During the past few decades, oceanographers and other scientists have found significant variations in Southern Ocean biogeochemical processes from year to year. Some of the more significant of these interannual variations are the ice extent and concentration, the composition of herbivore communities, and the distributions and reproductive success of bird and marine mammals.

Surprisingly-because it is so central to the food web-little is known about how phytoplankton production varies from year to year or what role these variations may play. The production system in the Ross Sea consists predominantly of two major functional groups: diatoms and *Phaeocystis antarctica*, a colonial haptophyte. In this project, we will collect time-series data and assess the interannual variations of phytoplankton in the southern Ross Sea, Antarctica.

The Ross Sea provides a unique setting for such an investigation. We can build on a de facto, already ongoing time-series because so many studies have been conducted in the Ross Sea in the past decade. Also, it has been established that there are fewer species there (relative to some other sites) and that seasonal production is as great as anywhere in the Antarctic. Most important, seasonal production of the total phytoplankton community (as well as its two functional groups) can be estimated from late summer nutrient profiles.

Interannual variations in seasonal production (and of the two major taxa of producers) may be an important factor in the growth and survival of higher trophic levels within the Ross Sea food web. They also shed light on

the natural variability of the suite of biogeochemical processes in the region. Having a scientific handle on that baseline of change is important, because of the scientific efforts to model how climate may change in the future. As climate changes, so certainly will biology be profoundly affected, and to model and evaluate such change we need to place it in the context of natural interannual variability. (BO-047-O; NSF/OPP 00-87401)

Evolutionary loss of the heat-shock response in antarctic fishes.
Gretchen Hofmann, Arizona State University-Tempe.

Evolution has crafted a way for organisms to respond to the stress of abrupt environmental changes, in particular a sudden elevation of temperature. Commonly viewed as a universal characteristic of organisms, the heat-shock response (HSR) triggers previously inactive genes to synthesize one or more classes of molecular chaperones, known as heat-shock proteins (Hsps). But what about Antarctica, where such a sudden burst of heat is so unlikely? In previous studies on a cold-adapted, stenothermal antarctic teleost fish, *Trematomus bernacchii*, it was determined that this adaptational response has been lost over evolutionary time.

If evolution at subzero temperatures has indeed altered the gene expression patterns for molecular chaperones in antarctic fish, then the study of how cells respond to temperature at a molecular level may be a legitimate new frontier in biology. At this stage, however, though HSR-perhaps the quintessential example of the environmental regulation of gene expression-has been well described at the cellular level, there is little information on how the response is actually regulated in ectothermic animals in a natural environment.

We hope to build on that evolutionarily significant observation by examining this profound change in the environmental regulation of gene expression on two levels. First, we will try to establish how widespread the loss of the HSR might be in the suborder Notothenioidei, including antarctic and nonantarctic members of the group. Second, we will try to determine the nature of the lesion in gene expression that accounts for the loss of the expression of stress-inducible genes in antarctic species. Both of these objectives will entail experiments on closely related, cold temperate species from New Zealand waters.

Ultimately, the lesions in the Hsp gene expression in antarctic notothenioids may serve to highlight aspects of the "cellular thermostat" and to provide key information about the actual molecular response mechanism triggered by environmental stress. The results should contribute to our knowledge of the environmental physiology and evolutionary biology of the antarctic notothenioid fishes, as well as enhance our understanding of the extreme stenothermality in these fish. (BO-134-O; NSF/OPP 00-87971)

Gene expression in extreme environments: Extending microarray technology to understand life at its limits.
Alison Murray, Desert Research Institute.

One of the most difficult challenges facing scientists who study life in extreme environments is observing the organisms in situ and then extrapolating those observations into descriptions that capture both the unique aspects of life and the adaptations required for survival. Antarctic marine psychrophiles (cold-loving organisms) provide an excellent model group of extreme microorganisms to study; since very little is known about their biological and functional diversity or about the metabolic adaptations they have developed to live at -1.8ºC.

This project is centered not only on identifying the organisms present in antarctic marine waters, but it also entails a significant effort in technology development of DNA microarrays for use with environmental samples. Our approach includes sequencing DNA cloned directly from the environment, then querying the identified open reading frames by hybridization to freshly expressed mRNA. We hope to determine relative levels of gene expression for a suite of genes from bacterial and archaeal genomes with functions essential for cellular growth, as well as functions related to cold tolerance and membrane adaptation.

This effort to develop functional genomics approaches for the study of microorganisms in situ may well have

fairly direct practical benefits. High-throughput screening of putative psychrophillic genes isolated from extreme environments may identify new genes for use in biotechnology. By discovering these genes in natural (extreme) environments, we can learn about gene function and develop hypotheses on potential metabolic roles, without the requirement of microbial cultivation.

The details of this work entail

- sequencing six large bacterial genomic DNA fragments isolated directly from antarctic marine psychrophiles,
- constructing two different types of DNA microarrays designed to identify genes being actively expressed in uncultivated microorganisms (archaea and bacteria) living in the subzero marine waters of the Antarctic,
- optimizing specific aspects of microarray technology for use with environmental samples, and
- developing a transferable methodology that will be useful for other researchers in accessing information on gene expression directly from the natural environment. (BO-179-O; NSF/OPP 00-85435)

Effects of the iceberg B-15 on the breeding success of the Cape Crozier emperor penguin colony.
Gerald Kooyman, Scripps Institution of Oceanography, University of California-San Diego.

This project will investigate the effects of the iceberg, B-15, on the emperor penguin (*Aptenodytes fosteri*) population at Cape Crozier. The population of this southernmost of the emperor penguin colonies, although sometimes fluctuating radically, had grown steadily in past years, with as many as 1,200 chicks counted. This probably represented an adult population of 2,400 to 3,000 birds. However, in 2001, after B-15 ground into the Cape Crozier area during the winter breeding period, no live emperor chicks were found. The colony had disappeared.

The goal of this project is to determine whether the colony will re-establish itself at Cape Crozier or relocate to a different site nearby. If the colony re-establishes at Cape Crozier, we will estimate the previous year's loss with a census of the chicks present this year. The destruction of the colony site by the iceberg in 2001 represents a natural experiment to examine the resilience of breeding emperor penguins to short-term disasters. Broader impacts of this study are related to the historical importance and worldwide interest in this colony, since it was the first emperor penguin colony discovered and has probably the longest census record of any penguin colony. (BO-197-O; NSF/OPP 02-24957)

Monitoring the effects of tourism and environmental variability on Adélie penguins at Palmer Station, Antarctica.
William R. Fraser, Polar Oceans Research Group.

The potential consequences of antarctic tourism on Adélie penguins (*Pygoscelis adeliae*) have been debated for more than 20 years. However, the rapid proliferation of these activities since 1970, particularly on the Antarctic Peninsula, has not only forced an extension of these questions to wildlife populations in general, but also colored them with a sense of urgency and controversy that has polarized opinions. The key concern is that continued increases in these activities will eventually overcome the ability of research to address critical issues in a timely and biologically meaningful manner. This is a valid concern, since studies to examine human impacts have either not been implemented at critical sites or are limited in scope because of logistic and experimental constraints.

Understanding how tourism might affect Adélie penguins rests fundamentally on the need to quantify and understand the natural variability manifested by breeding populations over spatial and temporal scales. However,

although it is generally recognized that without these data it will be difficult to critically assess any localized changes from tourism, this ecosystem approach is expensive and complex and is not likely to be justified by the need to understand tourist impacts.

We will continue a tourist monitoring program underway at Palmer Station as part of a large ecosystem-scale study. Palmer Station mirrors current patterns in tourism and tourist-wildlife interactions in the western Antarctic Peninsula. It also provides unique opportunities for research on human impacts. This includes the presence of long-term databases that document environmental variability over time and space scales in both marine and terrestrial habitats, as well as the ability to examine potential tourist impacts as part of controlled experiments.

This research is expected to capitalize and expand on two key findings to date. One is the discovery of a previously unrecognized source of variability in the Adélie penguin population that results from interactions between landscape geomorphology and changing patterns of snow deposition due to climate warming. The other is the observation that penguins breeding in less desirable landscapes may be more susceptible to cumulative impacts induced by the presence of human activity.

These findings have important implications for understanding interactions between climate change and ecosystem response, and for detecting, mitigating, and managing the consequences of human activities such as tourism. (BO-198-P; NSF/OPP 01-30525)

Effects of foraging on the lipid biochemistry of freely diving Weddell seals (*Leptonychotes weddellii*).
Michael Castellini, University of Alaska-Fairbanks, and Lorrie Rea, University of Central Florida.

Freely diving Weddell seals in Antarctica offer a unique opportunity to follow the biochemistry and physiology of nutrient use in a large carnivore.

A study of the in vivo nutritional biochemistry of foraging in a free-ranging, large mammalian carnivore has never been attempted because of the logistics of obtaining multiple blood samples, conducting turnover studies, and measuring digestive chemistry while the animal is actively foraging. Although such studies can be conducted in laboratory or zoo settings, they are limited to using captive animals whose feeding times and diets are typically constrained by humans.

A unique opportunity exists in the Antarctic. For several decades, the Weddell seal has been the focus of natural diving physiology studies using isolated holes through the sea ice near McMurdo Station. The seal has access to a single ice hole where it routinely returns to breathe, sleep, digest, and so on. With the use of blood-sampling catheters, we have been able to collect serial samples whenever the seal returns to the surface between dives. During such experiments, these seals actively catch and digest their prey. However, all previous studies have focused on diving physiology per se because they were designed to examine how the animals tolerated long periods of holding their breath. Any observations on nutritional chemistry were incidental and not part of the study design.

We propose to take this method in a new direction by examining how Weddell seals process nutrients while foraging. Like all seals, Weddell seals rely primarily on lipid metabolism for daily energy. Therefore, we will examine the kinetics of lipid uptake and use during active foraging bouts. We will obtain blood samples from freely diving animals and use labeled traced experiments to quantify lipid turnover rates and separate the lipid pool into its various components. We also will compare lipid uptake and use in adult seals and in pups, which are biochemically adapted for massive and rapid lipid use while nursing.

This project will provide important insights into mammalian biochemistry. These data will be important not only to antarctic ecosystem studies, but also to the entire field of lipid metabolism in mammals and the study of carnivore biology. (BO-199-O; NSF/OPP 01-30417)

Latitudinal effects of ultraviolet radiation on bacterioplankton: BRIDE OF TABASCO science of opportunity cruise.
Wade H. Jeffrey, University of West Florida.

Our objectives are to examine changes in response to ultraviolet radiation along the latitudinal transect between Punta Arenas and San Diego. Ultra-violet irradiance intensity will change by almost an order of magnitude along the transect. We will conduct daily experiments with surface waters collected at dawn to

- examine changes in the response of bacterioplankton and phytoplankton to changes in incident irradiance using radioisotope incorporation assays;
- study levels of ultraviolet-induced DNA damage under changing incident irradiance;
- evaluate the role of nutrients, particularly iron, in determining microbial response to ultraviolet radiation;
- field-test an iron bioreporter system; and
- examine changes in bacterial community structure and function in response to ultraviolet radiation. (BO-200)

Viral dynamics and the Southern Ocean iron-cycle.
Steven Wilhelm, University of Tennessee-Knoxville.

The bioavailability of iron has been shown to regulate primary production in high-nutrient low-chlorophyll (HNLC) marine environments such as are found in Antarctica. More than 99 percent of dissolved iron in HNLC systems is organically complexed, and these iron-ligand complexes represent (at least indirectly) the pool of iron that is available to marine plankton. However, the character and source of the iron-binding ligands in sea water are unknown.

Recent research has suggested that the activity of naturally occurring viral populations provides enough organically complexed iron to regenerate the concentrations of dissolved iron measured in an HNLC coastal upwelling system in a time frame consistent with the growth of the phytoplankton community. Our goal is to participate in the upcoming (January-February 2003) *FeCycle* analysis and, in collaboration with scientists from the University of Otago (New Zealand) and the University of Delaware, to determine the rate at which viruses recycle iron back to the marine microbial community.

A 12-day experiment in the vicinity of 46º 30' S, 178º 30' E will build on 4 years of research in this region. The overall objective of the project is to collect information that will allow us to develop a preliminary model for the cycling of iron in this system in the absence of iron fertilization. (BO-229-O; NSF/OPP 02-28895)

Prevention of environment-induced decrements in mood and cognitive performance.
Laurence A. Palinkas, University of California-San Diego.

Cognitive performance degrades with residence in Antarctica, and mood alteration fits a seasonal pattern during extended residence. Although these changes suggest psychological responses to physiological adaptations to cold and dim light, the exact mechanisms are poorly understood.

Our first objective is to determine whether long-term exposure to cold temperatures and/or to dim light is associated with significant changes in cognitive performance and emotional well-being:

- Is physiological adaptation to cold and/or adaptation to dim light independently or synergistically associated with decrements in cognitive performance and emotional well-being?

- Do personnel at South Pole Station experience greater physiological adaptation and decrements than personnel at McMurdo Station?

We also wish to determine whether these decrements can be prevented or minimized by pharmacologic interventions and/or phototherapy:

- What are the effects of combining liothyronine sodium with levothyroxine sodium versus supplementation with tyrosine (a precursor to both thyroid hormone and catecholamines) and daily phototherapy?

- Is phototherapy used in combination with a pharmacologic agent more effective than either intervention used alone.

In phase I, we will establish computer-testing protocols, develop an effective placebo capsule, package the necessary drugs, and test the validity and reliability of computer-administered cognition and mood protocols with 30 hypothyroid outpatients on constant thyroid hormone replacement and 30 age- and sex-matched healthy controls in New Zealand.

In phase II, 50 members of the 2002 winter crews, 35 at McMurdo Station and 15 at South Pole Station, will be randomized in a double-blind crossover design into 1 of 2 treatment groups (20 subjects in each group) and 1 control group (10 subjects). Baseline measurements will be conducted, and treatment groups will be switched after a 1-month washout period. Mood and memory testing will comprise 5 assessments over 12 months. Treatments consist of 50 micrograms (mcg) of levothyroxine sodium plus 12.5 mcg of liothyronine per day, 150 milligrams per kilogram of tyrosine per day, and a placebo.

In phase III, a similar design will be used to evaluate the effectiveness of phototherapy, alone and in combination with the more effective of the two pharmacologic interventions.

Our research will lead to an improved understanding of the specific environmental conditions and physiological mechanisms that affect behavior and performance in the Antarctic, help develop countermeasures for circannual oscillations of mood and cognitive performance, and contribute to a reduction in accidental injuries at high latitudes. (BO-321-M/S; NSF/OPP 00-90343)

LONG-TERM ECOLOGICAL RESEARCH

A U.S. researcher works in a temporary laboratory set up in the McMurdo Dry Valleys for the McMurdo Long-Term Ecological Research project. *(NSF photo by Peter West)*

Ecology has taken its place among science's vital, strategic disciplines, thanks to an ever-greater awareness of how the web of life and the Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, the National Science Foundation's Long-Term Ecological Research (LTER) program, begun in 1980, has grown into a network of 24 research sites, established to acquire long-term data sets from Alaska to Puerto Rico to Antarctica. Such a geographical spread is necessary to collect information on a variety of ecosystem types, such as grassland, desert, forest, tundra, lake, stream, river, and agricultural and coastal systems.

To enhance understanding of ecological phenomena, the program focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of these distinctive ecosystems. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology: one near Palmer Station in the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

The Palmer Station/Antarctic Peninsula LTER program is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year by year), what happens to the antarctic marine community? That is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER program was initiated during the 1991-1992 season with the installation of an automatic meteorological station, annual research cruises in the austral summer, and a focused research program at the station facility. During the austral fall and spring seasons, process-study research cruises develop data that can be compared with data collected from other coastal systems in the Antarctic Peninsula.

Due to its unique site, the McMurdo Dry Valleys LTER project is more wide ranging and focuses on interdisciplinary study of aquatic and terrestrial ecosystems in a cold desert region of Antarctica. The area is one

of the most fascinating and contrarian spots on Earth. In fact, it is almost unearthly. Scientists from the National Aeronautics and Space Administration who wondered what conditions might be like on Mars came here, an island of rock in a sea of ice, the largest ice-free area in Antarctica, where winds howl, where what little water there is dessicates or evaporates, and where the only creatures that can survive are microorganisms, mosses, lichens, and relatively few groups of invertebrates. Higher forms of life are virtually nonexistent.

Thus, LTER projects based here take advantage of perhaps the coldest and driest ecosystem on Earth, where life approaches its environmental limits; as such, this may be seen as an "end-member" in the spectrum of environments included in the LTER network. Why is it necessary to conduct long-term ecological research in such a place? All ecosystems depend on liquid water and are shaped to varying degrees by climate and material transport; but nowhere is this more apparent than in the McMurdo Dry Valleys. In very few of Earth's environments do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as in the dry valleys. Therefore, this site may well be an important, natural, regional-scale laboratory for studying the biological effects of climate changes attributable to human activity. While the antarctic ice sheets respond to climate change on the order of thousands of years, the glaciers, streams, and ice-covered lakes in the McMurdo Dry Valleys often experience nearly immediate (and sometimes profound) change. As such, this area would be one of the first where the effects of climate change in Antarctica should be observed.

The overall objectives of the McMurdo Dry Valleys LTER are to understand the influence of physical and biological constraints on the structure and function of dry valley ecosystems and to understand the modifying effects of material transport on these ecosystems. Though driven by the same basic processes found in all ecosystems (microbial use and remineralization of nutrients, for example), these dry valley ecosystems lack many of the confounding variables, such as diverse and fecund biota and many levels of plants and higher animals, inherent in other ecosystem research.

The role of natural legacy on ecosystem structure and function in a polar desert: The McMurdo Dry Valley LTER program.
W. Berry Lyons, Ohio State University.

The largest ice-free area in Antarctica can be found in the McMurdo Dry Valleys, located on the western shore of McMurdo Sound. Among the most extreme deserts in the world, the dry valleys are the coldest and driest of all the LTER sites. Consequently, biological systems are limited to microbial populations, microinvertebrates, mosses, and lichens. Yet complex trophic interactions and biogeochemical nutrient cycles develop in the lakes, streams, and soils of the dry valleys. In the austral summer, solar energy produces glacial meltwater, providing vital water and nutrients that have a primary influence on the ecosystems. Such material transport and climatic influences shape all ecosystems, but nowhere is this more apparent than in the McMurdo Dry Valleys.

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the dry valley landscape as a context to study biological processes and to explore material transport and migration. During the second phase of this LTER project, we are extending our research by continuing to investigate the McMurdo Dry Valleys as an "end-member" system, hoping to better ascertain the role of past climatic legacies on ecosystem structure and function. We will test a series of eight hypotheses in three major focus areas-hydrology, biological activity/diversity, and biogeochemical processes-by continuing monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate, both now and in the past. Current patterns of biological activity and diversity reflect past and present distributions of water, nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the

linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes in the past and present are controlled by the availability of water. We continue to focus on the integration of the biological processes within and among the lakes, streams, and terrestrial ecosystems that comprise the McMurdo Dry Valley landscape. Our interdisciplinary research team will continue to use modeling and other integrative studies to synthesize data and to examine the McMurdo Dry Valleys ecosystem.

During the 2002-2003 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

- Paleoclimatology, paleoecology, and meteorological data collection. (BM-042-D; NSF/OPP 98-10219)
  Peter T. Doran, University of Illinois-Chicago.

- Glacier mass balance, melt, and energy balance: Climate monitoring in Taylor, Wright, Victoria, and Beacon valleys. (BM-042-F; NSF/OPP 98-10219)
  Andrew Fountain, Portland State University.

- Chemistry of streams, lakes, and glaciers. (BM-042-L; NSF/OPP 98-10219)
  W. Berry Lyons, Ohio State University.

- Flow, sediment transport, and productivity of streams; water quality of Lake Fryxell; water loss from the streams to the atmosphere by sampling water-content changes. (BM-042-M; NSF/OPP 98-10219)
  Diane McKnight, University of Colorado.

- Lake pelagic and benthic productivity: Microbial food webs. (BM-042-P; NSF/OPP 98-10219)
  John Priscu, Montana State University-Bozeman.
- The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota. (BM-042-V; NSF/OPP 98-10219)
  Ross A. Virginia, Dartmouth College.
- The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota. (BM-042-W; NSF/OPP 98-10219)
  Diana Wall, Colorado State University.

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Hugh W. Ducklow, College of William and Mary.

The Palmer Long-Term Ecological Research Project (PAL LTER) seeks to understand the structure and function of the antarctic marine and terrestrial ecosystem in the context of physical forcing by seasonal to interannual variability in atmospheric and sea-ice dynamics, as well as long-term climate change. The PAL LTER grid is designed to study marine and terrestrial food webs consisting principally of diatom primary producers, the dominant herbivore antarctic krill, *Euphausia superba*, and the apex predator Adélie penguin, *Pygoscelis adeliae*. An attenuated microbial food web, consisting of planktonic Archaea and bacterivorous protozoa, is also a focus of study.

This project monitors western Antarctic Peninsula ecosystems annually over a grid of oceanographic stations and seasonally at Palmer Station. Sea-ice extent and variability affect changes at all trophic levels. In recent years, sea ice has diminished in response to a general warming in the region. Long-term population trends of ice-dependent Adélie penguins provide a clear example of the impact of this trend in the Palmer study region. Adélie populations at the five major rookeries located near Palmer Station and studied for the past 30 years have all shown a gradual decrease in numbers. The western Antarctic Peninsula, the site of PAL-LTER research, runs perpendicular to a strong climatic gradient between the cold, dry continental regime to the south, characteristic of the interior, and the warm, moist maritime regime to the north. More maritime conditions appear to be replacing the original polar ecosystem in the northern part of the peninsula as the climatic gradient shifts southward. To date, this shift appears to be matched by an ecosystem shift along the peninsula, as evidenced by declines in Adélie penguins, which require longer snow-cover seasons.

We hypothesize that ecosystem migration is most clearly manifest by changes in upper-level predators (penguins) and certain polar fishes in predator foraging environments because these longer-lived species integrate recent climate trends (and because species are more sensitive indicators than aggregated functional groups). We hypothesize that in the years ahead, analogous modifications will be manifest at lower trophic levels in the marine parts of the system, although these changes are likely to be seen only through long-term studies of ecosystem boundaries along the peninsula.

By studying extant food webs in both the marine and terrestrial environments, we will continue to investigate ecosystem changes at lower trophic levels, in response to the continued, dramatic climate warming and shifts in the poleward climatic gradient along the Western Antarctic Peninsula.

During the 2002-2003 field season, the following studies will be conducted as part of the LTER project:

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
William R. Fraser, Polar Oceans Research Group. (BP-013-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Maria Vernet, Scripps Institution of Oceanography. (BP-016-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Douglas G. Martinson, Columbia University. (BP-021-L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Langdon B. Quetin, University of California-Santa Barbara. (BP-028-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Robin M. Ross, University of California-Santa Barbara. (BP-028-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment.
Raymond C. Smith, College of William and Mary. (BP-032-P/L; NSF/OPP 02-17282)

Long-term ecological research on the antarctic marine ecosystem: Climate change, ecosystem migration, and teleconnections in an ice-dominated environment. (microbial and carbon flux).
Hugh Ducklow, College of William and Mary. (BP-045-P; 0087872)

Transport and fate of persistent organic pollutants in antarctic coastal seas.
Hugh Ducklow, College of William and Mary.

Being distant and largely isolated from the industrialized world, the antarctic region is typically considered pristine. In the past two decades, however, concern about long-range atmospheric transport of persistent organic pollutants (POPs) has escalated across the globe. POPs are highly stable organic compounds that persist in the environment, accumulate in the fatty tissues of most living organisms, and are generally toxic to humans and wildlife. They come from pesticides and industrial and combustion processes.

But Antarctica is not just another place that could suffer the random, transboundary drifting of these noxious substances. Its polar location and unparalleled climatic characteristics raise unique issues of atmospheric transport, cold condensation, and deposition on sea ice. Because the climate changes so dramatically, sea ice comes and goes, covering as little as 4 million square kilometers (sq km) in February to as much as 20 million sq km in September. Vast webs of microbial life undergo seasonal production and decomposition. Antarctic food webs are thus vulnerable to those POPs that do migrate that far.

Cooperating with the Palmer Long-Term Ecological Research program (LTER) and sailing on its winter cruise on the R/V *Nathaniel B. Palmer*, we hope to document the accumulation of selected model POPs in sea ice and the water column along the west Antarctic Peninsula. We also hope to add to the burgeoning global data set on the biological/chemical processes that influence the rate of POP decline, turnover, and residence time. (BP-045-P; NSF/OPP 00-87872)

OCEAN AND CLIMATE STUDIES

Ocean scientists work aboard the U.S. research ship *Laurence M. Gould* in waters near the Antarctic Peninsula. *(NSF/USAP photo)*

Though it borders the world's major oceans, the Southern Ocean system is like no other in the world, with 4 times more water than the Gulf Stream and 400 times more than the Mississippi River. It is a sea where average temperatures do not reach 2°C in the summer, where even the water itself is so distinctive that it can be identified thousands of miles away in currents that originated here. These Antarctic Bottom Waters provide the major source of cooling for the world's oceans. In fact, if the Earth is a heat engine, Antarctica should be viewed as its circulatory cooling component.

The climate in Antarctica is also unique, linked as it is to the extreme conditions of the land and sea below the troposphere (the inner region of the atmosphere, up to between 11 and 16 kilometers). This ocean/atmosphere environment defines and constrains the marine biosphere and in turn has a dynamic relationship with the global ocean and with weather all over the planet. Few major energy exchanges on Earth can be calculated without factoring in these essential antarctic phenomena. As such, they are both an indicator and a component of climate change.

The Ocean and Climate Studies program sponsors research that will improve understanding of the high-latitude ocean environment, including the global exchange of heat, salt, water, and trace elements; there is also an emphasis on sea-ice dynamics, as well as the dynamic behavior and atmospheric chemistry of the troposphere. Major program elements include the following:

- **Physical oceanography:** The dynamics and kinematics of the polar oceans; the interaction of such forces as wind, solar radiation, and heat exchange; water-mass production and modification processes; ocean dynamics at the pack-ice edge; and the effect of polynyas on ventilation.

- **Chemical oceanography:** The chemical composition of sea water and its global differentiation; reactions among chemical elements and compounds in the ocean; fluxes of material, within ocean basins and at their boundaries; and the use of chemical tracers to map oceanic processes across a range of temporal and spatial scales.

- **Sea-ice dynamics:** The material characteristics of sea ice, from the level of the individual crystal to the large-scale patterns of freezing, deformation, and melting.
- **Meteorology:** Atmospheric circulation systems and dynamics, including the energy budget; atmospheric chemistry; transport of atmospheric contaminants to the antarctic; and the role of large and mesoscale systems in the global exchange of heat, momentum, and trace constituents.

Solar radiation processes on the east antarctic plateau.
Stephen G. Warren and Thomas Grenfell, University of Washington.

This project is an experimental study of solar radiation processes near the surface at Dome C, the French-Italian station in East Antarctica. It will be carried out in cooperation with the Laboratoire de Glaciologie et Geophysique de l'Environment in Grenoble, France. The emphasis will be on the reflection of sunlight by snow and the transmission of sunlight through clouds. The observations we gather will be relevant to climate, remote sensing, and the physics of ice and snow.

We will measure transmissions of solar radiation through clouds, and these measurements will be used to obtain effective cloud optical depths to estimate cloud radiative forcing, with applications in climate models. We will develop a method to obtain this information from pyranometers alone so that the historical record of solar radiation observations in the antarctic interior can be analyzed for climatological information on clouds.

Observations of the angular pattern of solar radiation reflected from the snow surface will allow us to validate information from satellite-derived atmospheric profiles. Using radiative transfer modeling through the atmosphere, we will reconcile measured surface reflection functions with the empirical functions obtained from advanced Vidicon high-resolution radiometers on the polar orbiting satellites of the National Oceanic and Atmospheric Administration.

Finally, the spectral peak of snow albedo will be accurately located in order to resolve a discrepancy over the spectral absorption of pure ice in the visible to near-ultraviolet range. (OO-201-O; NSF/OPP 00-03826)

Antarctic Meteorological Research Center (AMRC).
Charles R. Stearns and George Weidner, University of Wisconsin-Madison.

The Antarctic Meteorological Research Center (AMRC) was created in 1992 to improve access to meteorological data from the Antarctic. The AMRC's mission is to conduct research in observational meteorology and the stewardship of meteorological data, along with providing data and expert assistance to the antarctic community to support research and operations. The AMRC plans to fulfill its mission by

- continuing to maintain and expand, as appropriate, the long-term record of all meteorological data on Antarctica and the adjacent Southern Ocean, and make these data available to the scientific community for multidisciplinary use (special attention will be given to obtaining data not normally or readily available by other means);

- continuing to generate satellite products, specifically but not limited to antarctic composite imagery, and expand and improve on them as much as possible;

- conducting research in observational meteorology, especially with regard to climatological analyses and case studies; and

- continuing to conduct and expand, as appropriate, educational and public outreach activities associated with antarctic meteorology and related fields

Using available meteorological interactive processing software and other standard computing tools, we will collect data from all available sources for processing, archiving, and distribution.

The mission of the AMRC not only includes the opportunity to advance the knowledge of antarctic meteorology, but with the free availability of its data holdings, the AMRC gives others the opportunity to advance the frontiers of all antarctic science. Continuing educational outreach activities on meteorology and the Antarctic, an important component of this work, have the potential to raise the science literacy of the general public, as well as the level of K-12 science education. (OO-202-O; NSF/OPP 01-26262)

Atmospheric oxygen variability in relation to annual-to-decadal variations in terrestrial and marine ecosystems.
Ralph F. Keeling, Scripps Institution of Oceanography.

Oxygen, the most abundant element on Earth, comprises about a fifth of the atmosphere. But much of the Earth's oxygen resides in other chemical species (in water, rocks, and minerals) and, of course, in the flora and fauna that recycle it (both directly and as carbon dioxide) through photosynthesis and respiration. Thus, scientists are interested in measuring the concentration of molecular oxygen and carbon dioxide in air samples; our project includes a subset of sample collections being made at a series of baseline sites around the world.

These data should help improve estimates of the processes whereby oxygen is cycled throughout the global ecosystem, specifically through photosynthesis and atmospheric mixing rates, and also improve predictions of the net exchange rates of carbon dioxide with biota, on land and in the oceans. An important part of the measurement program entails developing absolute standards for oxygen-in-air in order to ensure stable long-term calibration. In addition, we are conducting surveys of the oxidative oxygen/carbon ratios of both terrestrial- and marine-based organic carbon, hoping to improve the quantitative basis for linking the geochemical cycles of oxygen and carbon dioxide.

These results should help enhance our understanding of the processes that regulate the buildup of carbon dioxide in the atmosphere and of the change processes, especially climate change, that regulate ecological functions on land and in the sea. (OO-204-O; NSF/OPP 95-Okeel)

Validation of the Atmospheric Infrared Sounder (AIRS) over the antarctic plateau.
Von Walden, University of Idaho.

The antarctic plateau is an ideal ground site for calibrating and validating infrared satellite instruments. In terms of surface temperature and emissivity, the large continental ice sheet is one of the most homogeneous land surfaces on Earth. Ground-based measurements of upwelling infrared radiation between 8 and 12 micrometers are very nearly equal to those measured by satellites because of the minimal atmospheric emission and

absorption found on the antarctic plateau. Therefore, accurate measurements of spectral infrared radiance made at the surface there can provide data to validate the National Aeronautics and Space Administration's (NASA's) Atmospheric Infrared Sounder (AIRS).

In our fieldwork at Dome Concordia, we will use the polar atmospheric emitted radiance interferometer (PAERI) to measure upwelling and downwelling spectral infrared radiance. In addition, an infrared thermometer will map changes in surface radiation at spatial scales similar to the ground footprint of AIRS. Radiosondes will be launched to obtain temperature and humidity profiles. A ground-based global positioning system unit will attempt to measure the extremely low values of total precipitable water (about 1 millimeter in the summer). The zenith and azimuth of the PAERI viewing angle will be adjusted to match the AIRS viewing angle of the surface and through the atmosphere.

The measurements and data we gather will help validate the AIRS and contribute to the growing body of knowledge about spectral infrared radiance. (OO-213-M; NASA grant)

Mesoscale, seasonal, and interannual variability of surface-water carbon dioxide in the Drake Passage.
Taro Takahashi and Colm Sweeney, Lamont-Doherty Earth Observatory, Columbia University.

The Southern Ocean provides an important component of the global carbon budget. Cold surface temperatures, with consequent low vertical stability, ice formation, and high winds, produce a very active environment where the atmospheric and oceanic reservoirs readily exchange gaseous carbon. The Drake Passage is the narrowest point through which the Antarctic Circumpolar Current and its associated fronts must pass; this so-called chokepoint provides the most efficient site to measure the latitudinal gradients of gas exchange.

Working from the R/V *Laurence M. Gould*, we will use equipment designed to measure both dissolved carbon dioxide and occasional total carbon dioxide in the surface waters during transects of the Drake Passage. This work extends similar measurements made aboard R/V *Nathaniel B. Palmer* and complements other data collected on surface temperatures and currents. These several data sets, supplemented by satellite imagery, will enable scientists to estimate the net production and carbon export by the biological community, as well as the basic targets-a quantitative description of the sources of dissolved carbon dioxide variability and a calculation of carbon dioxide fluxes between the ocean and the atmosphere. (OO-214-O; NSF/OPP 00-03609)

AnSlope, Cross-slope exchanges at the Antarctic Slope Front.
Arnold Gordon, Stanley Jacobs, and Martin Visbeck, Lamont-Doherty Earth Observatory, Columbia University.

What is the role of the antarctic slope front (ASF) and continental slope morphology in the exchanges of mass, heat, and freshwater between the shelf and oceanic regimes, in particular those leading to outflows of dense water into intermediate and deep layers of the adjacent deep basins and world ocean circulation?

The importance to the global ocean circulation and climate of cold water masses originating in the Antarctic is understood, but the processes by which these water masses enter the deep ocean circulation are not. Our program, called AnSlope, will address this problem. Our primary goal is to identify the principal physical processes that govern the transfer of shelf-modified dense water into intermediate and deep layers of the adjacent deep ocean, as well as understand the compensatory poleward flow of waters from the oceanic regime. The upper continental slope is the critical gateway for the exchange of shelf and deep ocean waters. Here the topography, velocity, and density fields associated with the nearly ubiquitous ASF must strongly influence the transfer of water properties between the shelf and oceanic regimes.

AnSlope has four specific objectives:

- determine the ASF's mean structure and the principal scales of spatial and temporal variability, and estimate the ASF's role in cross-slope exchanges and mixing of adjacent water masses;
- determine the influence of slope topography on frontal location and outflow of dense shelf water;
- establish the role of frontal instabilities, benthic boundary layer transports, tides, and other oscillatory processes on cross-slope advection and fluxes; and
- assess the effect of shear-driven and double-diffusive mixing, lateral mixing identified through intrusions, and nonlinearities in the equation of state on the rate of descent and the fate of outflowing, near-freezing shelf water.

We will address these objectives with an integrated observational and modeling program. We will perform a set of measurements whose basic elements are moorings, microstructure analysis, tracers, and basic tidal modeling. Three cruises over a 12- to 14-month period beginning in the austral summer of 2003 will provide the data. Moorings will be in place throughout this period. Existing Italian and German programs will provide enhancement and a test bed for our parameterizations of cross-front exchange. (OO-215-O; NSF/OPP 01-25172)

Measurements and improved parameterization of the thermal conductivity and heat flow through first-year sea ice.
Hajo Eicken and Martin Jeffries, University of Alaska-Fairbanks.

The sea-ice cover in the polar oceans strongly modifies ocean-atmosphere heat transfer. Most important, the ice cover thermally insulates the ocean, with sea-ice thermal conductivity determining the magnitude of the heat flow for a given ice temperature gradient. Despite its importance (second only to ice albedo), our knowledge of sea-ice thermal conductivity is limited to highly idealized models developed several decades ago. General circulation models (GCMs) and large-scale sea-ice models currently include overly simplistic parameterizations of ice thermal conductivity that are likely to contribute significantly to errors in estimating ice production rates.

We will carry out a set of field measurements from which the thermal conductivity of first-year sea ice will be derived as a function of ice microstructure, temperature, salinity, and other parameters. Measurements will be carried out by letting thermistor arrays freeze into the fast ice of McMurdo Sound, which represents an ideal natural laboratory for this type of measurement. To minimize errors and identify the most robust technique, we will collaborate with colleagues from New Zealand and compare different methodologies for measurement and analysis. We will also assess the impact of ice microstructure (spatial distribution of brine, crystal sizes) and convective processes on the effective rate of heat transfer.

Antarctic data will be compared with arctic thermal conductivity data sets to assess regional contrasts and the impact of different physical processes on heat flow and to arrive at a comprehensive, improved parameterization of ice thermal conductivity for large-scale simulations and GCMs. This component of the work will involve ice-growth modeling and collaboration with the Sea-Ice Model Intercomparison Project Team established under the auspices of the World Climate Research Program. This research will advance and improve

- our understanding of the processes and parameters controlling heat transfer and the thermal

conductivity of first-year sea ice,

- techniques for deriving thermal conductivity and heat flow data from thermistor arrays,
- our understanding of sea-ice processes and heat flow through the ice cover in McMurdo Sound,
- parameterizations of thermal conductivity for use in large-scale and high-resolution one-dimensional simulations, and
- the representation of first-year ice thermal properties (both antarctic and arctic) in GCMs. (OO-253-O; NSF/OPP 01-26007)

South Pole monitoring for climate change: Amundsen-Scott South Pole Station.
David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, South Pole Station.

The National Oceanic and Atmospheric Administration has been conducting studies to determine and assess the long-term buildup of trace atmospheric constituents that influence climate change and the ozone layer. Time-series analyses of long-term data provide insight into several phenomena of particular interest, including

- seasonal and temporal variations in greenhouse gases,
- the depletion of stratospheric ozone,
- transantarctic transport and deposition,
- the interplay of the trace gases and aerosols with solar and terrestrial radiation fluxes that occur on the polar plateau, and
- the development of polar stratospheric clouds over Antarctica.

Project scientists measure carbon dioxide, methane, carbon monoxide, stable isotopic ratios of carbon dioxide and methane, aerosols, halocarbons, and other trace constituents. Flask samples are collected and returned for analysis, while concurrent in situ measurements of carbon dioxide, nitrous oxide, selected halocarbons, aerosols, solar and terrestrial radiation, water vapor, surface and stratospheric ozone, wind, pressure, air and snow temperatures, and atmospheric moisture are made. Air samples are also collected at Palmer Station.

These measurements allow us to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. We collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (OO-257-O; NSF/OPP 90-17842)

Drake Passage high-density XBT/XCDT Program.
Janet Sprintall, Scripps Institution of Oceanography.

During each crossing of the research ship *Laurence M. Gould*, we intend to launch expendable bathythermographs (XBTs), supplemented by expendable conductivity-depth-temperature (XCDT) probes, to obtain high-density sections from which to study the seasonal variability and long-term change in the upper ocean structure of the Drake Passage, which is off the tip of South America. Whenever the distance between Antarctica and neighboring land is narrow, as in the Drake Passage and the area off the Cape of Good Hope, the Antarctic Circumpolar Current, which drives the waters in the Southern Ocean, is extremely strong.

The information we gather will lead to the establishment of a high-quality database that can be used to study the magnitude and depth of penetration of the seasonal signals, the connections to atmospheric forcing, and the effects of interannual variations such as those associated with the Antarctic Circumpolar Wave.

The sections obtained during these voyages will supplement the approximately 20 sections that we have been gathering and studying since September 1996. Our continuing data analysis will be carried out in cooperation with the Argentine Antarctic Institute in Buenos Aires. (OO-260-O; NSF/OPP 00-03618)

Collection of atmospheric air for the NOAA/CMDL worldwide flask sampling network, Palmer Station.
David Hofmann, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, Palmer Station.

The National Oceanic and Atmospheric Administration has been conducting studies to assess the long-term buildup of trace atmospheric constituents that influence climate change and the ozone layer. Time-series analyses of long-term data provide insight into several phenomena of particular interest, including

- seasonal and temporal variations in greenhouse gases,
- the depletion of stratospheric ozone,
- transantarctic transport and deposition,
- the interplay of the trace gases and aerosols with solar and terrestrial radiation fluxes that occur on the polar plateau, and

Personnel at Palmer Station collect air samples to be analyzed for carbon dioxide, methane, carbon monoxide, and stable isotopic ratios of carbon dioxide and methane. Flasks are also collected for analysis of halocarbons, nitrous oxide, and other trace constituents.

These measurements allow us to determine the rates at which concentrations of these atmospheric constituents change; they also point to likely sources, sinks, and budgets. We collaborate with climate modelers and diagnosticians to explore how the rates of change for these parameters affect climate. (OO-264-S; NSF/OPP ASA-0037)

Operation of an aerosol sampling system at Palmer Station.
Colin G. Sanderson, Environmental Measurements Laboratory, U.S. Department of Energy.

Radionuclides, some of which occur naturally in the surface air, are atoms emitting radioactive energy. It is

these, as well as nuclear fallout and any accidental releases of radioactivity, that the Environmental Measurements Laboratory's (EML's) Remote Atmospheric Measurements Program (RAMP) is designed to detect and monitor. Since 1963, EML, as part of the U.S. Department of Energy, has run the Global Sampling Network to monitor surface air. The RAMP system provides on-site analysis in 13 different locations around the world, including Palmer Station. Using a high-volume aerosol sampler, a gamma ray spectrometer, and a link to the National Oceanic and Atmospheric Administration's ARGOS satellite system, we continue sampling air at Palmer Station for anthropogenic radionuclides. (OO-275-O; NSF/OPP no number)

Antarctic automatic weather station program: 2001-2004.
Charles Stearns and George Weidner, University of Wisconsin-Madison.

A network of nearly 50 automatic weather stations (AWS) has been established on the antarctic continent and several surrounding islands. These facilities were built to measure surface wind, pressure, temperature, and humidity. Some of them also track other atmospheric variables, such as snow accumulation and incident solar radiation.

Their data are transmitted via satellite to a number of ground stations and put to several uses, including operational weather forecasting, accumulation of climatological records, general research, and specific support of the U.S. Antarctic Program, especially the Long-Term Ecological Research program at McMurdo and Palmer Stations. The AWS network has grown from a small-scale program in 1980 into a significant, extremely reliable data retrieval system that has proven indispensable for both forecasting and research. This project maintains and augments the AWS as necessary. (OO-283-M/S; NSF/OPP 00-88058)

Measurement of combustion effluent carbonaceous aerosols in the McMurdo Dry Valleys.
Anthony D. Hansen, Magee Scientific Company.

Though Antarctica remains comparatively pristine, there is heightened awareness of the impact the human presence and scientific work being undertaken there could have. To continue a series of assessments of the long-term environmental impact of the U.S. Antarctic Program's operations, we plan to generate a database detailing the abundance of carbonaceous aerosols ("black carbon") in the McMurdo Dry Valleys.

The Long-Term Ecological Research (LTER) study site in the McMurdo Dry Valleys supports a fragile, nutrient-limited ecosystem that could be significantly affected by human activities. Of special concern are deposits of particles from black carbon. These could result from the exhaust of diesel powered generators and helicopter operations in the McMurdo Dry Valleys; it is even possible that combustion products from McMurdo Station, about 100 kilometers away, could migrate to the study area. For three austral summers, we are deploying a real-time optical analyzer at the LTER site to measure the concentration of black carbon, polycyclic aromatic hydrocarbons, and other filterable organic compounds useful in fingerprinting combustion products. (OO-314-O; NSF/OPP 98-15140)

Shipboard acoustic doppler current profiling on the R/V *Nathaniel B. Palmer* and *Lawrence M. Gould*.
Teresa K. Chereskin, Scripps Institution of Oceanography, and Edward Firing, University of Hawaii.

Currents in the Southern Ocean have a profound influence on the world's oceans-and therefore on global temperature and the planet's ecosystem-yet some remote regions receive little scientific attention. This project is using doppler technology (sound-wave transmission and reflection) to explore the velocities of upper ocean currents. We are building a quality-controlled data set in one such sparsely sampled and remote region that nonetheless appears to play a significant role in global ocean circulation. We will develop and maintain a

shipboard acoustic doppler current profiler program on board the R/V *Nathaniel B. Palmer* and *Laurence M. Gould*.

Part of our long-term goal is to characterize the temporal and spatial velocity structure in the Southern Ocean. This entails measuring the seasonal and annual changes in upper ocean currents in the Drake Passage and then combining this information with similar temperature observations to see how the heat exchange varies and how it drives upper ocean currents. (OO-317-L; OO-315-N; NSF/OPP 98-16226)

GEOLOGY AND GEOPHYSICS

Mount Erebus on Ross Island, Antarctica's most active volcano, is the continent's only one with a persistent convecting lake of molten, alkali-rich phonolitic magma in its summit crater. This makes it one of the few volcanoes on Earth with nearly continuous, small explosive activity and continuous internal earthquake activity. Because of this, Mount Erebus provides the ideal natural laboratory to study certain phenomena with volcanoes and volcanic activity. *(NSF/USAP photo by Josh Landis)*

Antarctica is not only one of the world's seven continents, it also comprises most of one of a dozen major crustal plates, accounting for about 9 percent of the Earth's continental (lithospheric) crust. Very little of this land is visible, however, covered as it is by the vast East Antarctic Ice Sheet and the smaller West Antarctic Ice Sheet. These ice sheets average some 3 kilometers deep and form a virtual vault; 90 percent of the ice on Earth is here. And it is heavy, depressing the crust beneath it some 600 meters (m). These physical characteristics, while not static, are current. Yet Antarctica is also a time machine, thanks to the sciences of geology and geophysics, powered by modern instruments and informed by the paradigm of plate tectonics/continental drift.

Geologists have found evidence that there was once a forested supercontinent, which they call Gondwanaland, in the Southern Hemisphere. Before the Earth's constantly shifting plate movement began to break the continent up 150 million years ago, Antarctica was a core piece of this assembly; the land adjoining it has since become Africa, Madagascar, India, Australia, and South America. Though the antarctic plate has drifted south only about a centimeter a year, geologic time eventually yields cataclysmic results. The journey moved the antarctic plate into ever colder, high-latitude climates, at a rate of about 4°C for each million years; eventually conditions changed dramatically, and Antarctica arrived at a near polar position. This astounding story-written in the language of rock and fossils-is locked in beneath the ice and the sea, and in the bedrock below them both.

As the ice sheets developed, they assumed, through their interaction with oceanic and atmospheric circulation, what has become a key role in modulating global climate. As a bonus, the South Pole presents a strategic point to monitor the Earth's seismic activity. Antarctica is the highest continent on Earth (about 2,150 m above sea level), with its fair share of mountains and volcanoes; thus, many generic questions of interest to Earth scientists worldwide also apply to this region. Some specific issues of interest to the Geology and Geophysics program include the following:

- determining the tectonic evolution of Antarctica and its relationship to the evolution of the continents from Precambrian time (600 million years ago) to the present;

- determining Antarctica's crustal structure;

- determining how the dispersal of antarctic continental fragments may have affected the paleocirculation of the world's oceans, the evolution of life, and the global climate (from prehistoric times to the present);

- reconstructing a more detailed history of the ice sheets, identifying geological controls to ice-sheet behavior, and defining geological responses to the ice sheets on regional and global scales; and

- determining the evolution of sedimentary basins within the continent and along the continental margins.

These issues will all become clearer as scientists improve their models of where, when, and how crustal plate movement wrought Antarctica and its surrounding ocean basins. The Geology and Geophysics program funds investigation into the relationships between the geological evolution of the antarctic plate and the life and processes that can be deduced to accompany it-the paleocirculation of the world's oceans, the paleoclimate of the Earth, and the evolution of high-latitude biota. A current emphasis is the West Antarctic Ice Sheet program, focused on the smaller of the continent's two ice sheets and conducted jointly with the Glaciology program. Several important research support activities are underway as well:

- **Meteorites:** In a partnership with the National Aeronautics and Space Administration and the Smithsonian Institution, the program supports meteorite collection through the antarctic search for meteorites (ANSMET) and chairs an interagency committee that is responsible for curating and distributing samples of antarctic meteorites.

- **Mapping and geodesy:** In partnership with the U.S. Geological Survey, the program supports mapping and geodetic activities as an investment in future research in earth sciences. The U.S. Antarctic Resources Center (USARC) constitutes the U.S. Antarctic Program's contribution to the Scientific Committee on Antarctic Research library system for earth sciences information; housed here is the largest collection of antarctic aerial photographs in the world, as well as many maps, satellite images, and a storehouse of geodetic information.

- **Marine sediment and geological drill cores:** In partnership with the Antarctic Marine Geology Research Facility at Florida State University, the program manages and disseminates marine sediment and geological drill cores mined in Antarctica. The collection includes an array of sediment cores as well as geological drill cores from the Dry Valley Drilling Project, the Cenozoic Investigations of the Ross Sea drilling program, and the Cape Roberts Drilling Project. The facility fills requests for samples from researchers worldwide and also accommodates visiting researchers working onsite.

Multiple isotope analyses of soil sulfate and nitrate in the antarctic dry valleys.
Huiming Bao, Louisiana State University and Agricultural and Mechanical College, and David Marchant, Boston University.

We will quantify atmospheric deposition of sulfate and nitrate in the dry valleys region of southern Victoria Land and generate the first quantitative model for the origin, distribution, and postdepositional alteration of

atmospheric sulfate and nitrate in dry valley soils. Besides testing the hypothesis that landforms in the dry valleys have been stable for millions of years, our results will provide a valuable reference for quantitative soil development in hyper-arid deserts elsewhere on Earth and on Mars. We will conduct multiple stable isotopic analyses of the water-soluble oxy-anions, sulfate and nitrate, in soils of differing ages and parent materials.

Newly discovered spatial patterns in the oxygen-isotopic composition of sulfate in these soils call for the existence of two sulfate end members, sea-salt sulfate and biogenic sulfate. The latter refers to sulfates formed by the oxidation of reduced biogenic sulfur gases (e.g., dimethylsulfide) in the atmosphere. Isotopic analyses will differentiate between these two forms of sulfate. In addition, preliminary data on the oxygen-isotopic composition of nitrate from these soils reveal exceptionally large nitrate, oxygen-isotopic (O17) anomalies and a spatial pattern that reflects a single nitrate source rather than two, as is the case for sulfate. To quantify long-term atmospheric input of sulfate and nitrate and their subsequent mobility in dry valley soils, we propose to

- sample vertical soil profiles at centimeter- to subcentimeter-scale resolution;
- systematically analyze the oxygen-isotopic composition of sulfate and nitrate;
- examine soils of a wide range of radiometric ages and parent materials, including ancient volcanic ashes, colluvium, lodgement tills, and ice-sublimation tills; and
- construct a simple one-dimensional transport model for sulfate and nitrate in vertical soil profiles.

When combined with our existing chronology of dry valley soils (built up over the past 15 years), these analyses will, for the first time, quantify the rate and style of soil development and patterned ground evolution in the dry valleys. These quantitative data are of paramount importance if we are to advance our understanding of this ecosystem and provide baseline data for anticipated analyses on Martian regolith. (GO-051-O; NSF/OPP 01-25842); NSF/OPP 01-25330)

Antarctic mapping, geodesy, geospatial data, satellite image mapping, and Antarctic Resource Center management.
Jerry L. Mullins, U.S. Geological Survey.

Antarctic mapping, geodesy, geospatial data, satellite image mapping, and the Antarctic Resource Center (ARC) constitute some of the activities necessary for the successful operation of a multifaceted scientific and exploratory effort in Antarctica. Year-round data acquisition, cataloging, and data dissemination will continue in the ARC in support of surveying and mapping. Field surveys are planned as part of a continuing program to collect the ground control data required to transform existing geodetic data into an earth-centered system suitable for future satellite mapping programs and to reinforce extant control of mapping programs to support future scientific programs. Landsat (Land Remote-Sensing Satellite) data will be collected as funding permits to support satellite image-mapping projects. These maps will provide a basis for displaying geologic and glaciologic data in a spatially accurate manner for analysis. They will also support future expeditions by providing a basis for planning scientific investigations and data collection. In addition, spatially referenced digital cartographic data will be produced from published maps.

Geodetic projects are planned as part of a continuing program aimed at building a continent-wide geodetic infrastructure (GIANT) that will support a wide range of U.S. and international scientific research objectives by

- establishing and maintaining a framework of permanent geodetic observatories,
- extending and strengthening the existing network of stations linked to the International Terrestrial Reference Frame,
- establishing geodetic coordinates at identifiable points for georeferencing satellite image- mapping projects,
- maintaining and calibrating tide gauge instrumentation,
- carrying out absolute gravity measurements, the continental margins.
- applying new high-accuracy remote-sensing measurement technologies such as airborne laser altimetry and digital cameras, and
- expanding the online geodetic database with new and historical data.

The geodetic field program is supported by a cooperative arrangement with Land Information New Zealand. (GO-052-M/P/S; NSF/OPP 02-33246)

Stability of land surfaces in the McMurdo Dry Valleys: Insights based on the dynamics of subsurface ice and sand-wedge polygons.
Bernard Hallet, University of Washington.

As concerns grow over warming and the recent occurrence of seemingly extreme weather events, the dynamic nature of climate has received more public attention. In this context, understanding the inherent variability of the Earth's climate and how humans can and do affect the Earth's environment is becoming increasingly important. This project focuses on the landscape features and soils of Antarctica's dry valley region to provide a more complete understanding of past climatic and environmental conditions.

One important means of improving our understanding of the planetary climate system is to use the Earth as a natural laboratory to examine past behavior. One of the most extreme changes in the climate system during the past few million years was the transition from a warm period in the Pliocene to an ice-age world. Scientists believe that during this interval, relatively mild conditions in Antarctica gave way rapidly to intense glacial conditions, catalyzing the growth of what has become the largest ice sheet on Earth. This inference is based on geologic indicators of past climate, from which some scientists suggest that East Antarctica was relatively warm and largely free of glaciers about 3 to 4 million years ago (during parts of the Pliocene). The mild conditions ended abruptly, with rapid ice-sheet growth and development of the very cold, dry climate that now characterizes this region. A contrasting view, based on substantial geologic evidence, suggests that East Antarctica has been cold and the ice sheet stable for at least 8 million years, and perhaps considerably longer. These views lead to drastically different interpretations of the stability of the Earth's climate.

We hope that our research will help resolve this important dilemma by introducing independent new evidence and insights derived from studies of the stability of ground ice and land surfaces in the McMurdo Dry Valleys. We will study modern-day processes that have important implications for understanding the occurrence of

buried ice found recently in Beacon Valley. This specimen may be the oldest ice on Earth; if so, it will provide strong evidence of the long-term stability of the East Antarctic Ice Sheet and may also afford a rare glimpse into atmospheric conditions millions of years ago.

Specific processes to be investigated include

- exchange at the ground surface that affects ground temperature,
- water-vapor transport and other processes leading to the formation or loss of ice in the soil, and
- frost cracking due to contraction during rapid cooling of the frozen ground in the winter and resulting disruptions of the soil. (GO-053-O; NSF/OPP 97-26139)

Response of the East Antarctic Ice Sheet to middle Miocene global change.
David R Marchant, Boston University.

As evidence of global climate change continues to accumulate, scientists concentrate on models that might indicate what impacts such change could have. Among the most important questions is, What could happen to the east antarctic ice sheet? One of the largest known global climate shifts occurred in the Middle Miocene between about 15.6 and 12.5 million years ago. As the isotopic composition of oxygen in the oceans shifted, dramatic global cooling and reorganization of ocean circulation patterns took place. This significant and irreversible shift set the stage for modern oceanic and atmospheric circulation and for the bipolar ice ages that have dominated climate records for the past 12.5 million years. How did Antarctica respond to this great climate shift? Could growth of the antarctic ice sheet have initiated this shift? If so, how might future fluctuations in the volume of ice on East Antarctica influence atmospheric and oceanic circulation?

Recently there was an unexpected breakthrough in antarctic geology: discovery of Miocene-age volcanic ashes interbedded with surficial sediments in southern Victoria Land. These terrestrial deposits provide unambiguous data from which to generate precise climatic and glaciologic reconstructions of how the global climate changed and the ice sheet evolved. This site appears to be the only place in Antarctica where pristine, Miocene-age, unconsolidated deposits are preserved at the ground surface.

These data also permit scientists to address key questions such as,

- What contributing factors in Antarctica led to the abrupt global cooling about 14 million years ago?
- Does the Middle Miocene shift in the isotopic composition of the oceans signify a major expansion of east antarctic ice?
- Or does this isotopic shift instead reflect a change in ocean temperature or circulation?
- And a related question: When did cold, hyper-arid, polar-desert conditions (signifying the development of a polar East Antarctic Ice Sheet) first evolve? In analyzing these deposits, we expect to obtain a precise chronological sequence, based on 50 laser-fusion isotopic analyses of in situ volcanic ashes and 20 cosmogenic, exposure-age analyses of ancient deposits. We also expect to develop a coeval record of

the Miocene paleoclimate, based on textural changes in alpine drifts; the areal distribution of ice-marginal lakes; the abundance of dated, patterned ground and ventifact pavements; and the geochemistry of buried soils and volcanic-ash deposits. (GO-054-O; NSF/OPP 98-11877)

The Ferrar magmatic mush column system, Dry Valleys, Antarctica.
Bruce D. Marsh, Johns Hopkins University.

The Earth's basic structure was formed by processes involving the crystallization of magma (molten rock). Operating on billion-year time scales, these processes have produced a wide diversity of rock types. In turn, these different elements comprise the continents and the ocean basins-the basic surface features of the Earth. Yet many of the details of these physical and chemical processes remain obscure.

Present-day volcanism exemplifies this overall process of differentiation; so many different varieties of lava erupt, yet scientists have not been able to relate this diversity to the prolonged and detailed deep-Earth processes that undoubtedly generate it. Solidified bodies of magma (plutons) that were once deeply buried and are now exposed through erosion also furnish evidence, but most often how these plutons relate to the magmatic-volcanic system is not clear.

This research is pointed at this fundamental problem: we will examine magma crystallization processes by studying sills (magmatic sheets) from the Ferrar Group in Antarctica. These studies should expose the relationship of plutonism to volcanism and may provide some important insights into planetary magmatism. The Ferrar magmatic system of the McMurdo Dry Valleys (Ferrar-DV) exemplifies the emerging global paradigm. Sills occur in stacks, connected below to a deep-seated magmatic source and above to a volcanic center.

The world's major magmatic systems reveal this pattern, since they tend to occur at ocean ridges (e.g., Kilauea, Mount Etna, Stillwater, and Rum, among many others). Only the Ferrar-DV, however, clearly reveals the critical physical and chemical connections between the deep, mush-dominated system and the near-surface, pre-eruptive sill system.

This project seeks to ascertain the full physical and chemical nature of the Ferrar-DV magmatic system, by

- fully delineating its vertical and horizontal extent and explaining how it was established,
- explaining the mechanics of formation of the Dais layered intrusion,
- producing a map of Ferrar rocks throughout the dry valleys, and
- producing a three-dimensional model of the opx tongue and feeder system.

The central science goal is to elucidate a rarely seen transition between plutonic and volcanic systems, one that may have implications fundamental to planetary magmatism. (GO-056-O; NSF/OPP 98-14332)

ANSMET (the antarctic search for meteorites).
Ralph Harvey, Case Western Reserve University.

Since 1976, ANSMET (the antarctic search for meteorites) program has recovered more than 10,000 meteorite

specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons:

- First, although meteorites fall at random all over the globe, the likelihood of finding a meteorite is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low; this makes the East Antarctic Ice Sheet the perfect medium.

- Second, along the margins of the sheet, ice flow is sometimes blocked by mountains, nunataks, and other obstructions; this exposes slow-moving or stagnant ice to the fierce katabatic winds, which can deflate the ice surface and expose a lag deposit of meteorites (a representative portion of those that were sprinkled throughout the volume of ice lost to the wind). When such a process continues for millenia, a spectacular concentration of meteorites can be unveiled.

It is important to continue recovering antarctic meteorites because they are the only currently available source of new, nonmicroscopic extraterrestrial material. As such, they provide essential "ground truth" about the composition of asteroids, planets, and other bodies of our solar system. ANSMET recovers samples from the asteroids, the Moon, and Mars for a tiny fraction of the cost of returning samples directly from these bodies.

During the 2002-2003 field season, ANSMET's main field party (8 people) will visit the Goodwin Nunataks and MacAlpine Hills region near the headwaters of the Beardmore Glacier. Goodwin Nunataks was last systematically searched in the 1999-2000 season, when more than 400 specimens were recovered. About half of the exposed blue ice in this area remains to be searched. MacAlpine Hills was visited in the 1987 and 1988 seasons, with 126 meteorites recovered. This season we hope to complete the systematic searching begun during those previous visits.

A second team consisting of 4 people will be deployed to the Pecora Escarpment region via South Pole Station and will be intensively supported by light aircraft to allow "survey-level" searches of several smaller icefields in the region. In addition to recovering meteorites, the goal for this group will be to identify the potential these icefields hold for more detailed searches during future seasons. (GO-058-O; NSF/OPP 99-80452)

Intrusive architecture and flow directions in southern Victoria Land.
Thomas H. Fleming, Southern Connecticut State University; Stephen Marshak and Alan Whittington, University of Illinois; and Anne Grunow, Ohio State University.

The dispersal of Gondwanaland represents one of the largest breakups of a supercontinent in Phanerozoic times. This breakup was associated with the emplacement of a large Jurassic mafic-igneous province that extended across the Karoo (southern Africa), Ferrar (Antarctica), and Tasman (Australia) regions and comprised continental flood basalts and extensive intrusive dolerites (other igneous rocks). Models linking development of the large (over 3,000 kilometers) Ferrar province to a mantle plume, a major magma conduit, or multiple sources make testable predictions about magma transport patterns within the province.

In our pilot study, we will use several different techniques aimed at evaluating these models and providing a greater understanding of the emplacement mechanisms, flow directions, and magmatic architecture associated with the Ferrar mafic intrusive province in southern Victoria Land. Our research will include mapping intrusive geometry based on structural field studies and geochemical correlation techniques. Further, we will use anisotropy of magnetic susceptibility, as well as mesoscopic and petrofabric flow indicators, to evaluate magma flow directions within the intrusive complex.

The results we will obtain will help resolve remaining questions about the geometry, propagation, and flow patterns in mafic large igneous provinces and provide a deeper understanding of the relationships between mantle plumes, basaltic magmatism, and continental breakup. (GO-062-M; NSF/OPP 01-26106, NSF/OPP 01-25634, NSF/OPP 0125737)

Calibration of cosmogenic argon production rates in Antarctica.
Paul R. Renne, Berkeley Geochronology Center.

We intend to establish the systematics of cosmogenic argon production required to establish its measurement as a routine surface exposure dating tool analogous to existing methods based on helium-3, beryllium-10, carbon-14, neon-21, and aluminum-26. Cosmogenic argon offers advantages over existing cosmogenic chronometers in that it is stable (hence applicable to long-term or ancient exposure dating) and less prone to diffusive loss than helium or neon.

Argon-38 is produced principally by spallation of calcium and (probably) potassium, and it is most easily measured using neutron-irradiated samples, as has been done routinely on extraterrestrial samples for decades. Our initial measurements on antarctic samples demonstrate the viability of this method for terrestrial samples and suggest an average production rate of greater than 100 atoms/gram-calcium/year. Existing data suggest that argon-38/calcium exposure ages younger than 105 years can be accurately determined by this method.

Further work on calcic minerals (apatite, sphene, clinopyroxene, plagioclase, calcite) whose exposure histories are constrained by helium-3 and neon-21 concentration data will be used to determine the calcium-derived production rate. Analogous work on potassium-rich minerals (potassium-feldspars, micas) will be used to constrain the production of argon-38 from potassium, which should theoretically be comparable to that from calcium when the same neutron-activation method is used.

Our analytical work will use existing samples plus new samples to be collected from the dry valleys of Antarctica to maximize cosmic radiation dosage for purposes of calibration. Laboratory studies of the retentivity of argon-38 in appropriate minerals will be used to help evaluate our results and guide future applications. (GO-064-O; NSF/OPP 01-25194)

Improved Cenozoic plate reconstructions of the circum-antarctic region.
Steve Cande, U.S. Air Force Technical Application Center, and Joann Stock, California Institute of Technology.

Well-constrained Cenozoic plate reconstructions of the circum-antarctic region are critical for examining a number of problems of global geophysical importance, among them

- relating plate kinematics to geological consequences in various plate circuits (Pacific-North America, Australia-Pacific);
- understanding what drives plate tectonics (which requires well-constrained kinematic information to distinguish between different geodynamic hypotheses); and
- understanding the rheology of the plates themselves, including the amount of internal deformation they can support and the conditions leading to the formation of new plate boundaries through the breakup of existing plates.

By obtaining better constraints on the motion of the antarctic plate with respect to other plates, and by better quantifying the internal deformation within Antarctica, we can contribute to understanding these fundamental issues.

We will analyze existing data to address several specific issues related to the motion of the antarctic plate. First, we will work on four-plate solutions of Australia-Pacific-West Antarctica-East Antarctica motion to constrain the rotation parameters for separation between East and West Antarctica by imposing closure on the circuit and using relevant marine geophysical data from all four of the boundaries. We will determine the uncertainties in the resulting rotation parameters based on the uncertainties in the data points. These can then be propagated in the plate circuit to address the issues listed earlier. Second, we will further quantify Pacific-West Antarctica rotation parameters for Tertiary time, using recently acquired well-navigated transit data from the icebreaking research ship *Nathaniel B. Palmer*. These parameters and their uncertainties will be used to assess plate rigidity and will be included in the circuit studies.

We will collect new marine geophysical data (on underway gravity, magnetics, and swath bathymetric data) on *Nathaniel B. Palmer* transit cruises. On one of the cruises, we propose to teach a formal class in marine geophysics to graduate and undergraduate students to integrate teaching activities with the data collection objectives. (GO-071-N; NSF/OPP 01-26340, NSF/OPP 01-26334)

Chemical weathering in Taylor Valley streams: Sources, mechanisms, and global implications.
W. Berry Lyons, Ohio State University, and Brent McKee, Tulane University.

Geochemists study the process of "chemical weathering" whereby rocks and minerals are transformed into new, fairly stable chemical combinations, primarily by such chemical reactions as oxidation, hydrolysis, ion exchange, and solution. Silicate hydrolysis is another such process that may have an impact on the global climate by consuming carbon dioxide, an important greenhouse gas. Generally, scientists have concentrated on more temperate climates to examine chemical weathering, because two of its most significant drivers are warmth and humidity.

However, recent data suggest that chemical weathering can and does occur in polar desert streams. At around 78°S, a number of ephemeral streams in Taylor Valley, Antarctica, that are associated with dry-based glaciers flow for 4 to 10 weeks each year. Solutes produced from chemical weathering (such as major cations), minor elements (for example, rubidium, cesium, lithium, strontium, and barium), bicarbonate, and dissolved reactive silica, as well as isotopes (87Sr/86Sr) have been found here. Although the mechanism/process of weathering is unknown, we hypothesize that the high chemical weathering rates that have been computed derive either from the high coincidence of freezing/thawing cycles and/or the unusual hydrologic behavior of the hyporheic zone in these streams.

Building on the initial work of the McMurdo Dry Valleys Long-Term Ecological Research team and others, we hope to better establish weathering rates and weathering mechanisms by examining the cryogenic processes whereby physical weathering may influence chemical weathering. To establish which materials are being weathered, we will analyze the suspended matter (in streams from the Lake Bonney basin in Taylor Valley and the Onyx Valley in Wright Valley) for their bulk chemistry and then compare these data with rock types in the valleys. To better ascertain solute sources, we will focus on uranium series geochemistry. Using major rock types from the Taylor and Wright Valleys, we will also conduct laboratory experiments to establish how microfracturing from freeze-thaw cycles could affect chemical weathering.

All of the data we gather will be used to draw analogies to historic weathering regimes on Earth during colder, drier climatic eras. (GO-074-O; NSF/OPP 00-87915)

Dry Valleys Seismograph Project.
Robert Kemerait, U.S. Air Force Technical Applications Center.

One recurrent issue in seismography is noise; that is, background phenomena that can interfere with clear and precise readings. The Dry Valleys Seismograph Project, a cooperative undertaking with the New Zealand Antarctic Program, was established to record broadband, high-dynamic-range, digital seismic data from the remote Wright Valley, a site removed from the environmental and anthropogenic noise that is ubiquitous on Ross Island.

The Wright Valley site provides one of the few locations on the continent with direct access to bedrock. The station there consists of a triaxial broadband borehole seismometer [100 meters (m) deep] and a vertical short-period instrument at 30 m. The seismological data are digitized at the remote location, telemetered by repeaters on Mount Newall and Crater Hill, and received eventually by the recording computer at the Hatherton Laboratory at Scott Base, where a backup archive is created.

These data will eventually reach the international seismological community; from Hatherton, they pass along a point-to-point protocol link to the Internet at McMurdo Station and thence to the Albuquerque Seismological Laboratory for general distribution. This data set has beautifully complemented the data from other seismic stations operated by the Albuquerque Seismological Laboratory at Amundsen-Scott South Pole Station, Palmer Station, and Casey, an Australian base. (GO-078-O; NSF/OPP-DoD MOA)

The Scotia Arc GPS Project: Focus on the Antarctic Peninsula and South Shetland Islands.
Frederick W. Taylor and Ian Dalziel, University of Texas-Austin.

The principal aim of the original Scotia Arc GPS (global positioning system) Project (SCARP) was to determine motions of the Scotia plate relative to adjacent plates and to measure crustal deformation along its margins with special attention to the South Sandwich microplate and Bransfield Strait extension. Our current research is confined to the part of the SCARP project that includes our GPS sites at Elephant Island, the South Shetland Islands, and the Antarctic Peninsula. The British Antarctic Survey provides data from two sites on the Scotia Arc for our project.

We plan to complete the measurements required to quantify crustal deformation related to the opening of the Bransfield Strait and the South Shetland microplate, and to identify any other independent tectonic blocks that our GPS data may reveal. These measurements will be done using ship support during the 2002-2003 season. Five years have passed since we did our first measurements, and it should be possible to determine quite precise horizontal velocities.

The British Antarctic Survey and the Alfred Wegener Institute have also recognized the importance of the Scotia plate and the Bransfield system. They, too, have used GPS to measure crustal motions in this region and duplicate a number of our sites. We expect to publish a joint paper and, also, to publish our own interpretations and data. Our network has several advantages that justify our collecting another set of data and analyzing it. One is that we have established and measured GPS sites on Smith, Low, and Livingston Islands, where other groups have not. These sites significantly extend the dimensions of the South Shetland microplate so that we can determine a more precise pole and recognize any sub-blocks within the South Shetland arc. Smith and Low Islands are near the end of the Bransfield Basin, where relative motion between the South Shetland microplate must somehow terminate, perhaps by faulting along an extension of the Hero fracture zone. Another advantage is that we conducted our measurements using fixed-height masts that eliminate all but a fraction of a millimeter of vertical error. Vertical motion associated with postglacial rebound should be on the order of several

millimeters per year, which will eventually be measurable. The fact that mid-Holocene shorelines emerged to more than 20 meters on some South Shetland arc islands suggests that vertical motion is significant. (GO-080-L; NSF/OPP 01-26472)

Mount Erebus Volcano Observatory: Gas emissions and seismic studies; Development of integrated seismic, geodetic, and volcanic gas surveillance instrumentation volcanic research; U-series isotopic constraints on the rates of magma genesis, evolution, and degassing at Mount Erebus.
Philip R. Kyle and Richard C. Aster, New Mexico Institute of Mining and Technology; Kenneth W. W. Sims, Woods Hole Oceanographic Institute.

Magmatism is one of the most fundamental dynamic processes of planetary interiors, yet our knowledge of the time-dependent parameters of basalt petrogenesis (solid mantle upwelling rate, melting rate, melt transport rate, magma storage time, and magma recharge rate) is quite limited. Magmatic processes such as melting, fractional crystallization, and magma chamber replenishment can fractionate parent/daughter ratios of U-decay series isotopes and thus create isotopic disequilibrium. Because the half-lives of U-series isotopes are comparable to the time scales of these processes, measurement of this isotopic disequilibrium in volcanic gases and mineral separates provides constraints on the duration and rates of magmatic processes.

Mount Erebus on Ross Island is Antarctica's most active volcano and also the only one with a persistent convecting lake of molten, alkali-rich phonolitic magma in its summit crater. This makes Mount Erebus one of the few volcanoes on Earth with nearly continuous, small explosive activity (two to six Strombolian eruptions daily) and continuous internal earthquake (seismic) activity. As such, it provides the ideal natural laboratory to study certain phenomena, specifically how gas is given off by magma and the seismic activity that results from a convecting magma conduit.

The small Strombolian eruptions eject volcanic bombs, thus providing samples of the magma with large, well-formed crystals. These bombs, plus older radiometrically dated lava flows around the summit of Mount Erebus, provide samples that constitute a unique opportunity to understand the timing of fundamental magmatic and volcanologic processes.

We intend to combine seismic studies and gas emission rate measurements in order to elucidate the nature and dynamics of the magmatic plumbing system, as well as eruptions and degassing from the lava lake. (The eruptions will be captured on video.) The gas studies will provide some of the first data available on carbon dioxide degassing from a highly alkalic magma system. They should also help evaluate how much lead from Mount Erebus (relative to lead released by marine aerosols) gets into the snow on the East Antarctic Ice Sheet and thus shed light on hypotheses about the anthropogenic origins of lead. Further goals of the gas studies are to

- examine the role of Mount Erebus as a source of gas and aerosols for the antarctic environment;
- understand the role of volcanism as a source of carbon dioxide emissions into the atmosphere, especially for highly alkalic magma;
- understand the evolution of the main volatile substances (water vapor, carbon dioxide, total sulfur, fluorine, and chlorine) in the Mount Erebus magmatic system, as well as their role in the eruptive behavior of the mountain; and

- correlate the nature of the gas emissions with the observed seismic activity.

For the seismic studies, we will install five integrated scientific instrument packages, all slightly different, depending on their location. All will include a broadband seismometer and dual-frequency global positioning system (GPS) units with 900 mega-Hertz spread spectrum transceivers to telemeter the data to McMurdo Station. Other equipment will include tiltmeters, infrasonics sensors, meteorological instruments (wind speed and directions, pressure and temperature), infrared radiometers (thermometers), and gas sensors. The packages will be battery powered and have solar panels and wind generators. We will also use GPS geodetic measurements for deformation studies to monitor the movement of magma inside the volcano.

Using U-series isotopes will allow us to examine the time scales of

- magma genesis and melt transport from the mantle,
- magma evolution and crystallization processes during magma storage in the crust, and
- magma degassing and recharge rates into the erupting magma chamber.

This is the first time U-series isotopes have been used in an integrated fashion to examine both gases and the associated magma. We hope to achieve a better understanding of the whole magmatic system, from magma formation by partial melting in the mantle through its evolution and finally to its degassing and open-system behavior in the lava lake.

Project team members will travel by helicopter to a camp at Fang Glacier to acclimatize and from there will go to the Lower Erebus Hut, where the work will be conducted. Travel to the work sites will be by helicopter and snowmobile. Monitoring equipment should ensure a nearly real time flow of data to the New Mexico Institute of Mining and Technology and the University Navstar Consortium.

The resulting data should enhance the collection of earthquakes we are using in a computer model of the interior of the volcano, as well as provide a tool scientists can use for conducting volcano surveillance, monitoring eruptions, and detecting subtle changes in the internal behavior of volcanoes. The broadband data will support a detailed study of the explosion mechanism, especially the very-long-period signals that are emitted. It should also help us detect temporal and spatial variability in earthquake mechanisms, which in turn might provide more insights into how variations in gas emissions could be implicated. (GO-081-O, GO-085-O; NSF/OPP 98-14921, NSF/OPP 01-16577, NSF/OPP 01-26269)

A global positioning system program to monitor motions in the bedrock of the West Antarctic Ice Sheet.
Ian Dalziel and Frederick Taylor, Institute of Geophysics, University of Texas; Robert Smalley, University of Memphis; and Michael G. Bevis, University of Hawaii.

The bedrock that underlies the West Antarctic Ice Sheet is not well described. Without a reliable evaluation of its history-both tectonic and ice-induced crustal motions-we will never be able to fully comprehend its past, present, and future dynamics. Without that knowledge, we can neither develop reliable global change scenarios for the future nor accurately factor the antarctic region into global plate movements. Currently, permanent global positioning system (GPS) networks that measure bedrock movement are established only on the fringe of the West Antarctic Ice Sheet; they cannot provide the data on subglacial volcanism, active tectonics, and ice streaming that are needed.

This project is focused on establishing baseline, long-term, reliable geodetic measurements of the crustal motion in the bedrock beneath the West Antarctic Ice Sheet. To obtain them, we are building a West Antarctica GPS Network (WAGN) of at least 15 GPS sites across the west antarctic interior-an area comparable to the area from the Rocky Mountains to the Pacific coast-over 2 years, beginning in the 2001-2002 austral summer.

The first summer, we initiated the WAGN network and tested the precision and velocities at the most critical sites. The embryonic network will begin to fill a major gap in GPS coverage by looking for potential bedrock movements. If crustal motions are relatively slow, meaningful results will only begin to emerge over the next 5 years or so. Once it is permanently established, however, the network should yield increasingly meaningful results. Indeed, the slower the rates turn out to be, the more important it is to start measuring early.

West Antarctic Ice Sheet bedrock is so scattered and remote that to erect a continuous string of permanent GPS stations would rival the building of the American transcontinental railroad. Instead, we plan to follow the multimodal occupation strategy, which entails roving receivers (based in permanent monuments set in solid rock outcrops) in place for only a short time at each site, providing data that can be ranged against permanent GPS readings elsewhere. Each of these "bases" can be converted in the future to a permanent, autonomous station when more logistics and satellite data linkage throughout West Antarctica are in place. When detectable motions occur, we can reoccupy the most critical sites, obtain more reliable velocities, and make decisions about reoccupying the entire network.

We expect the results of this project to establish important early indicators of crustal plate dynamics beneath the West Antarctic Ice Sheet. As scientists take these into account in refining their models, future measurements and a time-series of the geodetic data should gradually produce a more constrained picture of subglacial dynamics for the West Antarctic Ice Sheet-that is, plate rotations and both elastic and viscoelastic motions caused by deglaciation and ice-mass changes. (GO-087-M; NSF/OPP 00-03619)

TAMSEIS: A broadband seismic experiment to investigate deep continental structure across the east-west antarctic boundary.
Douglas Wiens, Washington University, and Sridhar Anandakrishnan, Pennsylvania State University.

Antarctica's outline looks generally like that of Australia, though half again as large; but beneath its enormous ice sheet lies evidence of its origin. East Antarctica has a bedrock continent-like foundation, while the ice sheet over West Antarctica-a third the area-in fact covers a series of islands. West Antarctica shares a geologic history with the Andes Mountains, the result of plates colliding and subducting. East Antarctica is more like a large chunk that broke free of the supercontinent Gondwanaland and drifted to a new position at the bottom of the world. The boundary between these two regions (with their disparate geologic pedigrees) is called the east-west antarctic boundary, and the crust and upper mantle here reveal many important and interesting distinctions that tell the basic story of the tectonic development of Antarctica.

In November 2000, we began making seismic measurements-using 3 different arrays and 44 seismic stations-all geared to evaluating geodynamic models of the evolution of Antarctica. To analyze the data, we will use a variety of proven modeling techniques, including body- and surface-wave tomography, receiver function inversion, and shear-wave splitting analysis.

One basic question is, How were the Transantarctic Mountains formed? Though widely considered a classic example of rift-flank uplift, there is little consensus about the exact mechanism. Many theories have been proposed, ranging from delayed-phase changes to transform-flank uplift. All of these make assumptions about the upper mantle structure beneath and adjacent to the rift-side of the mountain front.

Another focus will be the structure of the east antarctic craton, the highest ice block in the world. Was this anomalous elevation a prime driver in the onset of glaciation there? More to the point, how did it arise? Proposed models include isostatic uplift from thickened crust, anomalously depleted upper mantle, and thermally modified upper mantle, as well as dynamic uplift. How far the old continental lithosphere extends is also uncertain. In particular, it is not known whether the old lithosphere extends to the western edge of East Antarctica beneath the crustal rocks deformed during the Ross Orogeny (formation).

When completed and analyzed, this comprehensive set of data and theory testing will enable new maps of the variation in crustal thickness, upper mantle structure, anisotropy, and mantle discontinuity topography across the boundary of East and West Antarctica, providing a much enhanced foundation for understanding the geodynamics of the region. (GO-089-M; NSF/OPP 99-09603)

Logistics support for global seismographic network stations at the Amundsen-Scott South Pole and Palmer Stations.
Rhett Butler, Incorporated Research Institutions for Seismology.

Seismology, perhaps as much as any other science, is a global enterprise. Seismic waves resulting from earthquakes and other events can be interpreted only through simultaneous measurements at strategic points all over the planet. The measurement and analysis of these seismic waves are not only fundamental for the study of earthquakes, but they also serve as the primary data source for the study of the Earth's interior. To help establish the facilities required for this crucial scientific mission, IRIS (the Incorporated Research Institutions for Seismology) was created in 1985.

IRIS is a consortium of universities with research and educational programs in seismology. Ninety-seven universities are currently members, including nearly all U.S. universities that have seismological research programs. Since 1986, IRIS, through a cooperative agreement with the National Science Foundation (NSF) and in cooperation with the U.S. Geological Survey (USGS), has developed and installed the Global Seismographic Network (GSN), which now has about 126 broadband, digital, high-dynamic-range seismographic stations around the world; most of these have real-time communications.

The GSN seismic equipment at Amundsen-Scott South Pole Station and at Palmer Station was installed jointly by IRIS and USGS, which together continue to operate and maintain them. The GSN sites in Antarctica are vital to seismic studies of Antarctica and the Southern Hemisphere, and they contribute to the international monitoring system of the Comprehensive Test Ban Treaty. The state-of-the-art seismic instrumentation is an intrinsic component of the NSF effort to advance seismology and Earth science globally. (GO-090-P/S; NSF/OPP 00-04370)

Development of a luminescence dating capability for antarctic glaciomarine sediments: Tests of signal zeroing in the Antarctic Peninsula.
Glenn Berger, Desert Research Institute, and Eugene Domack, Hamilton College.

Paleoclimatology-the study and reconstruction of ancient weather and climate and their likely effects-is not an exact science. Climatic indicators, such as marine sediments that have been abundantly deposited around Antarctica over the past 2 million years, provide useful information about such phenomena as the waxing and waning of ice sheets, but only to the extent that these fossils can be accurately dated.

Traditionally, radiocarbon dating with the naturally occurring isotope carbon-14 has proved reliable for

specimens as old as 40,000 years, perhaps even 70,000 years, though problems such as the "reservoir effect" can limit its reliability and range. Moreover, increasing amounts of carbon-14 in the atmosphere have compromised its precision. A more recently developed method, photon-stimulated-luminescence sediment dating (photonic dating), has been used in temperate latitudes for aeolian and waterlain deposits and has proved reliable over a larger span of Quarternary time-from decades to hundreds of thousands of years. The question of whether this method can be reliably used in polar regions has yet to be answered, however.

Marine sediments in and around Antarctica pose special difficulty because polar conditions can limit the sunlight that detrital grains are exposed to. Since the thermoluminescent test involves reflecting the last time a sample was exposed to light (what is known as the clock-zeroing process), antarctic glaciomarine depositional settings and processes could undermine the reliability of photonic dating of antarctic marine sediments, and ages could be overestimated if grains were not exposed to daylight before deposition. Other processes could also compromise photonic dating. For example, transport of terrigenous suspensions by neutrally buoyant "cold-tongue" (mid-water) plumes may be common around Antarctica, yet the effect of such transport on luminescence zeroing is unknown. Typical marine cores taken near Antarctica may contain an unknown fraction of detrital grains from cold-tongue and near-bottom suspensions.

We will collect detrital grains from a variety of modern marine settings within the Antarctic Peninsula, where representative depositional processes have been documented and where logistics permit access.

By systematically studying the effectiveness of luminescence-clock-zeroing in antarctic glaciomarine settings, we hope to determine whether photonic dating can be reliably applied to antarctic marine sediments. In the process, we expect to develop refined criteria for selecting samples. If we can validate photonic-dating in this environment, scientists would gain a geochronometer extending well beyond the range of carbon-14 dating and be better able to answer a number of broader questions about past glaciations on and near the antarctic shelves. (GO-092-O; NSF/OPP 99-09665)

Antarctic Cretaceous-Cenozoic climate, glaciation, and tectonics: Site surveys for drilling from the edge of the Ross Ice Shelf.
Bruce P. Luyendyk and Douglas Wilson, University of California-Santa Barbara.

Many of the questions on the evolution of the East and West Antarctic Ice Sheets, antarctic climate, global sea level, and tectonic history of the West Antarctic Rift System can be answered by drilling into the floor of the Ross Sea. We will therefore conduct site surveys for drilling from the Ross Ice Shelf into the seafloor beneath. Climate data for this sector of Antarctica are lacking for the Cretaceous and Early Cenozoic. Questions include,

- Was there any ice during the Late Cretaceous?
- What was the antarctic climate like during the Paleocene-Eocene global warming?
- When was the Cenozoic onset of antarctic glaciation? When did glaciers reach the coast and when did they advance onto the margin?
- Was the Ross Sea shelf nonmarine in the Late Cretaceous? If so, when did it become marine?

Tectonic questions include,

- What was the timing of the Cretaceous extension in the Ross Sea rift and where was it located?
- What is the basement composition and structure?
- Where are the time and space limits of the effects of Adare Trough spreading?

Sampling at four drill sites was completed in the early 1970s but had low recovery and did not sample the Early Cenozoic. Other drilling has been restricted to the McMurdo Sound area of the western Ross Sea, and results can be correlated for the Victoria Land Basin but not eastward across basement highs. Further, Early Cenozoic and Cretaceous rocks have not been sampled.

Our surveys (including core samples and long profiles and detailed grids over potential drilling sites) will be conducted a kilometer or two north of the ice-shelf front. In 2 to 4 years, the northward advance of the shelf will cover surveyed locations and drilling can begin. The calving of giant icebergs from the ice front in the eastern Ross Sea have exposed 16,000 square kilometers of seafloor that has been covered for decades and has therefore not been explored. We will be able to map structure and stratigraphy below unconformity RSU6 farther south and east, study the place of Roosevelt Island in the Ross Sea rifting history, and determine subsidence history during the Late Cenozoic in the far south and east. Finally we will observe current sedimentary processes beneath the ice shelf in the newly exposed areas. (GO-152-O; NSF/OPP 00-88143)

Relative frequency and phase of extreme expansions of the antarctic ice sheets during the late Neogene.
Phillip Bart, Louisiana State University.

Expansions and contractions of the antarctic ice sheets have undoubtedly had a profound influence on the Earth's climate and global sea level. But the cryosphere in Antarctica is not a single homogenous entity. Science has yet to embrace its three primary components-the East Antarctic Ice Sheet, the West Antarctic Ice Sheet, and the Antarctic Peninsula Ice Cap-into a unified theory. Among these systems may be found differences in ice volume, substratum elevation, ice-surface elevation, and latitude.

Various lines of evidence do show, however, that the extent of ice in all three ice sheets has undergone significant retreats and advances; future episodes therefore appear inevitable. But exactly how and why the ice has fluctuated in this way is not certain. According to one line of reasoning, the land-based East Antarctic Ice Sheet has been relatively stable, experiencing only minor fluctuations since forming in the middle Miocene; by contrast, the marine-based West Antarctic Ice Sheet has been dynamic, waxing and waning frequently since the late Miocene. A conflicting hypothesis has the ice sheets advancing and retreating at about the same time.

Building on previous seismic-stratigraphic investigations of the continental shelves, we will use high-resolution seismic technology to focus on the frequency and phase of extreme advances of the ice sheets to the continental shelf. The data suggest a couple of useful scientific inquiries:

First, did extreme advances of the East Antarctic Ice Sheet and West Antarctic Ice Sheet occur across the shelf at about the same times and frequencies? This evaluation is possible because the East Antarctic Ice Sheet drains into the western Ross Sea continental shelf (Northern Basin), while the West Antarctic Ice Sheet drains into the eastern Ross Sea (Eastern Basin). Regional grids of high-resolution seismic data have been collected, but they are incomplete and cannot be used to determine the stratigraphic correlations from the Northern Basin to the Eastern Basin. We plan to collect high-resolution seismic data (approximately 2,000 line-kilometers) to

address this issue.

Second, did the Antarctic Peninsula Ice Cap advance frequently across the continental shelf? Some investigators have inferred that it has advanced across the shelf at least 30 times since the middle Miocene. If true, that activity would be an order of magnitude more frequent than the advances of the East Antarctic and West Antarctic Ice Sheets. Others interpret the seismic reflections differently and argue that the advances of the Antarctic Peninsula Ice Cap were far fewer. The existing high-resolution seismic grids from the Antarctic Peninsula contain only one regional strike line on the outer continental shelf; we collected high-resolution seismic data (approximately 1,000 line-kilometers) during a January 2002 cruise to the Antarctic Peninsula.

As part of this project, we are integrating our research into a graduate-level course at Louisiana State University and are also developing a pilot outreach program with a Baton Rouge public high school. Responding to scientific standards the Louisiana Department of Education recently adopted to reflect what 9th through 12th grade students should be able to do and learn, we are framing an experience to convey the excitement of conducting scientific research as a way to encourage them to pursue earth science at the university level. (GO-154-N; NSF/OPP 00-94078)

Aeolian processes in the McMurdo Dry Valleys, Antarctica.
Nicholas Lancaster and John Gillies, Desert Research Institute.

The McMurdo Dry Valleys provide a unique natural laboratory where scientists can study some fundamental processes in nature. Geomorphology is the study of landforms and the processes that shape them: for example, particles (sand, dust, snow, etc.) blown by the wind across a characteristic terrain. Wind-shear-stress partitioning analysis can create models to predict how such wind-borne particles, en route to a surface, may be affected by intervening elements that have a certain roughness-boulders, in the case of the McMurdo Dry Valleys. Ongoing studies of such regions (that is, sparsely vegetated to unvegetated rough surfaces) should provide models relevant to other arid areas on Earth and on Mars, as well as a range of rocky desert and sand sheet sites.

Using novel instrumentation called Irwin Sensors that was recently developed and has been tested in field and laboratory wind tunnel experiments, we will conduct studies of boundary layer winds and surface shear stress at four to six locations. This work will contribute to the testing and improvement of existing theoretical models for shear-stress partitioning. We hope the research will lead to the development of an improved and universally applicable model for estimating sediment transport by wind on surfaces that are covered by varying densities of nonerodible roughness elements. (GO-183-O; NSF/OPP 00-88136)

Ferrar basaltic tuff-breccias formed by direct eruption: Evaluating a hypothesis.
David Elliot, Ohio State University.

The Gondwanaland supercontinent broke up during Mesozoic times, and one part, now Antarctica, moved to the geographic south pole. A major magmatic event accompanied the breakup of the landmass. Voluminous basaltic magmas were erupted at the surface, and intrusive sills and dikes were emplaced at depth within the underlying sedimentary sequence. The record of this process in Antarctica shows extrusive rocks that include thick tuff-breccias (coarse pyroclastic rocks), believed to have formed by subsurface explosive interaction of basaltic magma and water in aquifers. This clash of materials with dramatically different temperatures is known as phreatomagmatic process.

Volcanic fields are commonly found in modern rift settings and include sites where rising magmas interact

explosively with water in aquifers or at the surface. The volcanic fields in parts of Antarctica, however, are unique. Compared with other well-documented examples, these basaltic pyroclastic rocks differ in terms of areal extent and thickness of deposits, depth of magma/water interaction, and dominance of basaltic tuff-breccia. We expect study of the paleovolcanology of these rocks to yield important new information on the origins and emplacement mechanisms of tuff-breccia deposits, as well as on the evolution of volcanic fields in which tuff-breccias form a significant component.

To better describe the processes involved in forming these exceptionally thick tuff-breccias, we hope to

- document the three-dimensional architecture of the basaltic pyroclastic rocks,
- establish the depth of magma/water interaction and evaluate aquifer recharge,
- establish the nature and extent of the volcanic field and its paleovolcanologic setting, and
- evaluate the hypothesis that these tuff-breccias are the result of direct eruption from volcanic vents.

Building on reconnaissance work, we expect the results of this study to have broad implications for understanding how phreatomagmatic processes form tuff-breccias, as well as the tectonic settings in which they occur. Results are also expected to develop the paleovolcanologic setting of the Transantarctic Mountains during the Jurassic. (GO-290-O; NSF/OPP 00-87919)

High-precision GPS survey support.
Bjorn Johns, University Navstar Consortium (UNAVCO).

UNAVCO provides year-round support for scientific applications of the global positioning system (GPS) to the U.S. Antarctic Program, which is supported and managed by the National Science Foundation's Office of Polar Programs. This support includes preseason planning, field support, and postseason followup, as well as development work for new applications. UNAVCO maintains a "satellite" facility at McMurdo Station during the austral summer research season, providing a full range of support services, including geodetic GPS equipment, training, project planning, field support, technical consultation, data processing, and data archiving.

UNAVCO also operates a community differential GPS base station that covers McMurdo Sound and Taylor Valley, provides maintenance support to the MCM4 continuous GPS station as contractual support to the National Aeronautics and Space Administration's GPS Global Network, and supports remote continuous GPS stations for scientific investigations.

Using GPS, vector baselines between receivers separated by 100 kilometers or more are routinely measured to within 1 centimeter (that is, 100 parts per billion). UNAVCO is also able to support researchers who are investigating global, regional, and local crustal motions where maximum accuracy (in the millimeter range) of baseline measurement is required. GPS measurements using portable equipment can be completed in a few hours or less. Such expediency lends itself to research applications in global plate tectonics, earthquake mechanics, volcano monitoring, and regional tectonics. (GO-295-O; NSF/OPP 99-03413)

GLACIOLOGY

Drillers for the University of Wisconsin's Ice Coring and Drilling Services (ICDS) clean ice out of the a recently reamed the hole so that they can fit seismic instruments into it. ICDS provides ice-coring and drilling services to NSF-sponsored researchers in the polar regions and at high-altitude sites. They maintain and operate a variety of drills and develop new systems when needed to provide the best possible ice cores, deploy instruments within the ice, and provide access to glacial beds. *(NSF/USAP photo by Kristan Hutchinson)*

Ice is indisputably the defining characteristic of Antarctica. The entire continent (with a few exceptions such as the McMurdo Dry Valleys and some lakes and mountains) is covered by a sheet of ice that has been laid down over eons, if the term "sheet" can be used to describe a dynamic mass that is several thousand meters (m) thick, that is larger than most countries, that rises over 2,000 m above sea level (and peaks in an ice dome nearly twice that high in the east), and that is heavy enough to depress the bedrock beneath it some 600 m. Actually, there are two sheets: the much larger East Antarctic Ice Sheet, which covers the bedrock core of the continent, and the smaller, marine-based West Antarctic Ice Sheet, which is beyond the Transantarctic Mountains and overlays a group of islands and waters.

The Glaciology program is concerned with the history and dynamics of the antarctic ice sheet; this includes research on near-surface snow and firn, floating glacier ice (ice shelves), glaciers, ice streams, and continental and marine ice sheets. These species of ice facilitate studies on ice dynamics, paleoenvironments (deduced from ice cores), numerical modeling, glacial geology, and remote sensing. Some current program objectives include the following:

- correlating antarctic climatic fluctuations (from ice-core analysis) with data from arctic and lower-latitude ice cores;
- integrating the ice record with terrestrial and marine records;
- investigating the physics of fast glacier flow with emphasis on processes at glacier beds;

- investigating ice-shelf stability; and

- identifying and quantifying the relationship between ice dynamics and climate change.

Dynamics and climatic response of the Taylor Glacier system.
Kurt Cuffey, University of California-Berkeley.

Taylor Glacier drains the Taylor Dome region of the East Antarctic Ice Sheet and terminates in Taylor Valley, one of the ice-free or dry valleys of southern Victoria Land. This glacier provides a crucial link between two intensively studied antarctic environments: the Taylor Dome, from which a 130,000-year ice-core paleoclimate record has recently been extracted, and the dry valleys, a pivotal ecological research site and a focus of geomorphology and glacial geology studies.

The goal of our research is to significantly improve our understanding of how Taylor Glacier flows and responds to changes in climate. It has been widely recognized that such information is central to understanding the changing physical environment of the Taylor Valley ecosystem and is required for linking interpretations of the Taylor Dome paleoclimate record to interpretations of the geomorphology and glacial geology of the dry valleys. This work will thus make an important contribution to ongoing efforts to exploit the Taylor Dome-dry valleys system to build a uniquely comprehensive view of regional long-term environmental changes.

Our work has two complementary components: field research and numerical modeling. Two field seasons will be used to measure velocity, surface strain rate, mass balance, ice thickness, glacier bed reflectance, and subglacial topography along a nearly complete longitudinal transect of the Taylor Glacier and along select cross-valley transects as well. This information will be used to constrain numerical models of ice and heat flow for the Taylor Dome-Taylor Glacier system. These calibrated models will be used to analyze the time-dependent response of the glacier to changes in climate. The synthesis of these results will be aimed at improving our understanding of the glacial geomorphology of Taylor Valley and at illuminating impacts on the Taylor Valley lakes ecosystem. (IO-161-O; NSF/OPP 01-25579)

Characteristics of snow megadunes and their potential effects on ice-core interpretation.
Theodore A. Scambos, University of Colorado-Boulder; Mary Albert, U.S. Cold Regions Research Laboratory; Mark Fahnestock, University of New Hampshire; and Christopher Shuman, National Aeronautics and Space Administration/Goddard Space Flight Center.

Vast portions of the east antarctic plateau are covered by snow megadunes: trough-and-crest features that appear to result from vigorous surface-atmosphere interaction. A study of these features will lead to an improved understanding of their formation and characteristics, which may help identify megadune-altered ice in ice cores.

Megadune extent today is 500,000 square kilometers (km). The climatology of dunefields, characterized by low accumulation and consistent katabatic winds, suggests that they may have been even more extensive in the past. Megadunes have amplitudes of 2 to 5 meters and wavelengths of 2 to 5 kilometers, and are slightly asymmetric, with shorter upwind faces. The crests, up to 100 km long, are perpendicular to local katabatic wind flow. Satellite images show that the dune pattern remains unchanged for decades. Near-zero accumulation rates imply that snow remains near the surface and susceptible to modification for many years, both through surface exposure and subsurface ventilation. We suspect that megadunes are formed by a sublimation/vapor-redeposition process that operates in a standing wave airflow pattern set up over the snow. The climate record eventually preserved beneath dunefields is thus unlikely to represent the regional conditions of deposition, but the degree of modification is unknown.

Over two successive seasons, we will study an area within the large, well-developed megadune field southeast of Vostok Station (now closed). Our objectives are to determine the physical characteristics of the firn across the dunes and to install instruments to measure the time variation of near-surface wind and temperature with depth to test and refine our hypotheses on megadune formation. Field study will consist of surface, snowpit, and shallow core sampling; ground penetrating radar profiling; topographic and ice-motion surveys; automatic weather station installation; accumulation/ablation measurements; subsurface temperature; and firn permeability.

We will also continue our remote-sensing study of the dunes continent-wide, as well as earlier studies of dune characteristics, and will model diffusion, ventilation, and vapor transport processes within the dune firn as well.

Megadunes are a manifestation of an extreme terrestrial climate (the limit of cold and dry) and may provide insights on past terrestrial climate or processes active on other planets. Megadunes are likely to represent an end-member in firn diagenesis and as such may have much to teach us about the processes involved. (IO-186-O; NSF/OPP 01-25570; NSF/OPP 01-25276; NSF/OPP 02-25992; NSF/OPP 01-25960)

Millennial-scale fluctuations of dry valleys lakes: Implications for regional climate variability and the interhemispheric (a)synchrony of climate.
Brenda L. Hall, University of Maine, and Glenn Berger, Desert Research Institute, University of Nevada.

What drives glacial cycles? Most researchers agree that Milankovitch seasonal forcing paces the ice ages, but how these changes are leveraged into abrupt global climate change remains unknown. A current popular view is that the climate of Antarctica and the Southern Ocean leads that of the rest of the world by a few thousand years or more. The character of deglaciation in Antarctica is that of a long gradual warming, rather than an abrupt change, although the paleoclimate record is not well defined. The most persistent challenge to the asynchrony hypothesis is the Taylor Dome ice core. Revision to the chronology has shown that the original interpretation of rapid climate change synchronous with deglaciation in Greenland was probably an artifact of very low accumulation rates.

Millennial-scale fluctuations of high-level, closed-basin, amplifier lakes in the dry valleys of Antarctica can shed some light on this issue: 150 radiocarbon dates of algae from deltas and shorelines record rapid oscillations of these high-elevation lakes that extend through the Holocene. This record has the potential to form an independent data set with which to test the synchrony of abrupt climate changes in Antarctica. However, this approach has several shortcomings, including the fact that the record in the Holocene and earlier is unclear, a lake-level record based on geomorphological features alone is discontinuous, and only levels higher than the present lakes are recorded.

The ideal way to address these problems is to integrate the geomorphological record with a series of cores taken from lake bottoms. We will obtain transects of long cores from Lakes Fryxell, Bonney, Joyce, and Vanda, using an approach designed to extract the greatest possible amount of data. Estimates of hydrologic changes will come from different proxies. Chronology will come from dating of carbonates, as well as luminescence sediment dating. Evaluation of the link between lake level and climate will come from modeling

Combination of the more continuous lake-core sequences with the spatially extensive geomorphological record will result in an integrated data set that extends back at least 30,000 years. This record will be compared with dry valley glacier records and ice cores to address questions of regional climate variability and then with other Southern and Northern Hemisphere records to assess the interhemispheric synchrony or asynchrony of climate change. (IO-196-M; NSF/OPP 01-24014 and NSF/OPP 01-24049)

Characterizing the onset of ice-stream flow: A ground geophysical experiment.
Sridhar Anandakrishnan and Richard B. Alley, Pennsylvania State University; Donald D. Blankenship and David L. Morse, University of Texas-Austin.

The goal of the onset experiment is to gain a better understanding of the transition zone of antarctic ice streams, where they switch from flow by internal deformation to flow dominated by basal sliding. We are conducting a tightly coupled suite of seismic, ground radar, and global positioning system (GPS) surveys of the onset regions of two west antarctic ice streams. Our goal is to characterize the englacial and subglacial environment within the ice stream, to the sides of the ice stream, and upflow of the onset of streaming, as well as across the transitions that separate these dynamic regimes. Our target sites for this program are the onsets and regions of major flow-reorganization of ice streams C and D.

For the antarctic ice streams of the Siple Coast, we define the transition from no-sliding (or all internal deformation) to motion dominated by sliding as the onset-region. To fully understand (and adequately model) the West Antarctic Ice Sheet, this onset region must be better understood. The lateral margins of the ice streams are also transitions that need to be better understood-they are conceivably subject to hypotheses similar to those for the onsets. The definition of the onset region is necessarily ambiguous because the formation of the ice streams is so poorly understood. The physical manifestation of the onset of streaming may be a change in the velocity (a peak in acceleration), a change in driving stress, or both. The relationship between glacial and subglacial parameters (bed roughness, bed wetness, fabric) and the onset is not known.

Hypotheses on controls of the location of the onset region range from the purely glaciologic to the purely geologic; the answer is likely to be some combination of the two. One purely glaciologic hypothesis asserts that the basal water layer thickness increases sufficiently to drown controlling obstacles at the bed and ice streaming then occurs. For this hypothesis, the boundaries of the catchment of the ice stream, the basal hydrologic potential, and the driving stress are the parameters that control both the onset and the margins of the ice stream. Thus, to model the ice sheet effectively, a detailed surface and bed topography map, an accumulation map, and geothermal heat flux would be needed.

The other extreme, a purely geologic hypothesis, would argue that the onset position and margins of the ice streams are entirely controlled by the subglacial sedimentary structure and properties. The sedimentary basins would determine where there are erosional source regions to produce till, which, when mobilized and of sufficient thickness, would cause the ice stream to form. Therefore, to model the ice sheet, we need a good subglacial geologic map showing the distribution, thickness, and properties of the sedimentary basins, which can be estimated from seismic and other geophysical work.

This work is being done in collaboration with the British Antarctic Survey, and we have received technical support, personnel, and equipment from the Incorporated Research Institutions for Seismology/Program for Array Seismic Studies of the Continental Lithosphere seismic instrument pool and the University Navstar Consortium GPS instrument pool. (IO-205-O; NSF/OPP 00-86297)

Western divide WAISCORES (Western Antarctic Ice Cores) site selection.
Howard B. Conway and Edwin Waddington, University of Washington.

The West Antarctic Ice Cores (WAISCORES) community has identified the western divide, between the Ross embayment and the Amundsen Sea, as the region for the next deep-ice core. The Ice Core Working Group (ICWG) has developed a document (*WAISCORES: Science and Implementation Plan, 2000*) that outlines the objectives of the drilling and the physical and chemical properties the core must have to achieve those

objectives.

The divide region spans more than 40,000 square kilometers, and preliminary site selection using airborne geophysical methods is now underway. This work has identified several potential drilling sites where the climate record should be best preserved throughout its long history of ice dynamics. We will make a suite of ground-based geophysical measurements to map spatial variations of iceflow, accumulation rate, internal layering, and ice thickness at two of the most promising sites. Our main investigative tools are high- and low-frequency ice-penetrating radar, repeat global positioning system surveys to calculate the present-day surface velocity field, synthetic aperture radar interferometry to calculate the regional velocity field, and short firn cores to calculate present-day accumulation rates.

Beyond the initial mapping and interpretation of internal layers and surface velocity, the measurements will be used to constrain our iceflow modeling. In particular, we will use these measurements and models to identify the specific site that is most likely to satisfy the following ICWG criteria:

- minimal disturbance from an iceflow,
- a record that extends back at least 50,000 years, and
- countable annual layers back 20,000 years.

A fourth criterion (good preservation of chemical species) will be addressed by others.

The first criterion (minimal disturbances) will be evident from the patterns of radar-detected internal layers. To address the other two, we will use the measurements as input for time-dependent iceflow and temperature models that predict depth variations of age, layer thickness, and temperature. The mismatch between the model predictions and the data eventually recovered from the core will help infer thinning and climate histories for the region, in addition to yielding an estimate of expected conditions before drilling. The information we gather will help guide site selection for the drilling. (IO-209-O; NSF/OPP 00-87345)

INTERNATIONAL TRANS-ANTARCTIC SCIENTIFIC EXPEDITION (ITASE)

An aerial view of the Nimrod Glacier as it flows the Transantarctic Mountains to the Ross Ice Shelf. *(NSF/USAP photo by Josh Landis)*

From its original formulation in 1990, the International Trans-Antarctic Scientific Expedition (ITASE) has coordinated the efforts of scientists from several nations to collect and interpret a continent-wide array of environmental parameters. This cooperative endeavor is geared to produce an improved description and understanding of environmental change in Antarctica over approximately the past 200 years. These original ITASE scientific objectives have been adopted as key science initiatives by both the International Geosphere Biosphere Program (IGBP) and the Scientific Committee on Antarctic Research (SCAR).

In 1996, the National Science Foundation (NSF) held a workshop to develop a science and implementation plan for the U.S. contribution to ITASE (called U.S. ITASE). Because of the long-standing U.S. research effort in West Antarctica, U.S. ITASE chose to focus its activities there. At the NSF workshop, participants developed a multidisciplinary research plan that integrates different approaches to environmental research. The primary scientific lenses through which West Antarctica is being examined are meteorology, remote sensing, ice coring, surface glaciology, and geophysics. The plan has four phases:

- In phase 1, meteorological modeling and remote sensing were used to plan sampling strategies in support of the major objectives of U.S. ITASE.

- Phase 2 initiates ground-based sampling over four study areas (corridors). Despite the broad spatial sampling of West Antarctica that was proposed, the logistic requirements for this sampling are modest and highly efficient.

- Phase 3 will continue ground-based sampling at a limited number of key sites where monitoring is required.

- Phase 4 follows through with data interpretation and modeling.

The U.S. component of ITASE (which has established a wide range of general scientific objectives) is trying to refine answers to the following questions:

- At what rate is the mass balance over West Antarctica changing?

- How do the major oceanic and atmospheric circulation systems (for example, the El Niño Southern Oscillation) influence the moisture flux over West Antarctica?

- How and why does climate (that is, temperature, accumulation rate, atmospheric circulation) vary over West Antarctica on seasonal, interannual, decadal, and centennial scales?

- What are the frequency, magnitude, and effect (local to global) of any extreme climate events recorded in West Antarctica?

- What is the impact of anthropogenic activity (for example, ozone depletion, science work, airborne pollutants) on the climate and atmospheric chemistry of West Antarctica?

- How much has biogeochemical cycling of sulfur, nitrogen, and carbon, as recorded in West Antarctica, varied over approximately the past 200 years

Radar studies of internal stratigraphy and bedrock topography along the U.S. ITASE traverse.
Robert W. Jacobel, Saint Olaf College.

The U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) conducts radar studies to determine the internal stratigraphy and bedrock topography of the terrain along the traverses. Radar provides immediate information on ice thickness and the structure of internal layers to those working in the field to help in the selection of core sites as the traverse proceeds. These data can also be used to site deeper, millennial-scale cores (planned at less frequent intervals along the traverse) and to provide a context for selecting the location of the deep inland core (planned for the future). In addition to mapping the traverse route, radar is used to examine a grid surrounding each of the core locations, to better characterize the accumulation and bedrock topography in each area.

This radar system works as a complement to the one operated by the Cold Regions Research and Engineering Laboratory. Theirs is a high-frequency radar, most suited to the shallower portion of the record down to approximately 60 meters (m); it can detect near-surface crevasses. Our radar system is most sensitive at depths below 60 m and is able to depict deep bedrock and internal geological layers deep in the ice. (IU-133-O; NSF/OPP 98-14574)

Science management for U.S. ITASE.
Paul A. Mayewski, University of Maine.

The Science Management Office (SMO) coordinates the effort developed for the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), the broad aim of which is to develop an understanding of the past 200 years of west antarctic climate and environmental change. ITASE is a multidisciplinary program integrating remote sensing, meteorology, ice coring, surface glaciology, and geophysics. To marshal this effort, SMO runs a series of annual workshops to coordinate the science projects that will be involved in ITASE. It also establishes and operates the logistics base that supports ground-based sampling in West Antarctica. (IU-153-A; NSF/OPP 97-25057)

U.S. ITASE glaciochemistry.
Paul A. Mayewski, University of Maine, and Loren D. Meeker, University of New Hampshire.

Among the research targets for scientists in the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) are the impact of anthropogenic activity on the climate and atmospheric chemistry of West Antarctica and the variations in biogeochemical cycling of sulfur and nitrogen compounds over the past 200 years.

Begun during the 1999-2000 austral summer, this 5-year project focuses on glaciochemical analyses of the major anions and cations to be found in shallow- and intermediate-depth ice cores collected on the U.S. ITASE traverses. The ionic composition of polar ice cores provides one of the basic stratigraphic tools for relative dating. These data can also be used to document changes in chemical-species source emissions, which in turn facilitate mapping and characterization of the major atmospheric circulation systems affecting the West Antarctic Ice Sheet. (IU-153-B; NSF/OPP 97-25057)

Snow and firn microstructure and transport properties: U.S. ITASE.
Mary R. Albert and Robert E. Davis, U.S. Army Cold Regions Research and Engineering Laboratory.

Not all valuable data are buried deep within the ice. The microstructure and bulk properties of snow and firn near and at the surface control the air/snow/firn transport processes; that is, how heat, vapor, and chemical species in air are incorporated into snow and firn. Since many of the snow and firn properties also affect how radiation behaves across different parts of the electromagnetic spectrum, such field measurements provide a valuable baseline profile against which to range complementary efforts that use remote sensing to map the spatial variations of snow, firn, and ice properties.

This project does the field and laboratory work to characterize snow and firn properties along the traverses of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) in West Antarctica. We provide field measurements of snow and firn properties near the surface [down to 2 meters (m)], including surface roughness, permeability, density, grain size, surface-to-volume ratio, and tortuosity. In the laboratory, firn cores from as deep as 20 m will be analyzed for these same properties and for their microstructure. Ultimately, we will develop a transport model to elucidate the nature of the air/snow/firn exchange and the firnification process at the various sites along the U.S. ITASE traverse. (IU-155-O; NSF/OPP 98-14676)

Hydrogen peroxide, formaldehyde, and subannual snow accumulation in West Antarctica: Participation in the west antarctic traverse.
Roger C. Bales, University of Arizona.

Atmospheric photochemistry leaves valuable traces in snow, firn, and ice; it has been verified that the efficiency of atmosphere-to-snow transfer and the preservation of hydrogen peroxide and formaldehyde are both strongly related to temperature and also to the rate and timing of snow accumulation. Thus, measurements of these

components in the firn and atmosphere will provide data needed to study changes in the tropospheric chemistry of the boundary layer over West Antarctica.

This project will collect samples and take atmospheric measurements along the traverses of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE). The wide-ranging extent of these traverses will focus on a variety of locations, covering much of the west antarctic region and reflecting a range of different depositional environments. The study of atmospheric chemistry requires good estimates of the interannual patterns of snow accumulation at subannual resolution in the pits and cores.

We will measure the concentration of seasonally dependent species (including hydrogen peroxide, nitrate, and chloride) on all samples. When supplemented by stable isotope and ionic analyses done by others, these data will provide a highly resolved accumulation record. We will then use a recently developed, physically based atmosphere-to-snow transfer model to elucidate the photochemistry that led to the concentrations in the snow/firn.

These snow chemistry data will also shed light on the interannual variability of snow accumulation over a wide area of West Antarctica. In addition, the data we develop on current atmospheric levels of hydrogen peroxide, higher peroxides such as methylhydroperoxide, and formaldehyde will constrain model boundary conditions and the state of photochemistry in the austral summer. (IU-158-O; NSF/OPP 98-14810)

Mass balance and accumulation rate along U.S. ITASE routes.
Gordon S. Hamilton, University of Maine.

The polar ice sheets-and the snow falling on them-are both important components of the global hydrological cycle. Yet because of their very large size and remote locations, we have only a limited understanding of their mass balance (rate of thickness change) or the spatial distribution of snow accumulation. Work conducted as part of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) seeks to improve this understanding.

This 5-year project, which is beginning its fourth year, involves measuring the rate of ice-sheet thickening (or thinning) at selected sites along flow lines, on ice divides, and along elevation contours. The measurements compare the vertical velocity of ice (obtained from precise global positioning system surveys of markers buried 5 to 20 meters deep in the surface firn) with the local, long-term, average snow accumulation rate that has been derived from ice-core stratigraphy. Earlier work demonstrates that very precise rates of thickness change can be measured using this technique.

We are also studying spatial variations in accumulation rates, probing the link between snow accumulation and surface topography. Continuously operating, autonomous instruments will be deployed at several closely spaced sites with very different slope gradients. The instruments will record snow accumulation, wind speed and direction, and firn compaction and temperature. These results will enable us to test hypotheses of the physical processes of snow deposition and erosion.

We will also investigate the iceflow effects on accumulation rates derived from U.S. ITASE ice-core records. At sites along flow lines, ice cores record the integrated accumulation rate history of the core site for a certain distance up-glacier. Changes in surface topography along this flow line will lead to apparent variations in accumulation rate in the ice-core record. By studying local ice dynamics (for example, horizontal velocities, surface slope) around each ice-core site, we will be better able to understand why the accumulation rate in the core records varies. (IU-178-O; NSF/OPP 98-15510)

The physical properties of the U.S. ITASE ice cores.
Debra Meese, U.S. Army Cold Regions Research and Engineering Laboratory.

As part of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), our objective is to examine, measure, and analyze the visual stratigraphy and physical and structural properties of ice cores spanning the past 200 years of snow accumulation in Antarctica.

- First, visual stratigraphy-this will delineate the annual layer structure for dating purposes and determine (to as great a depth as possible) the accumulation variability over the full length of a stratigraphically dated core.

- Second, depth-density profiles-the rate of snow and firn densification depends on both the in-situ snow temperature and the rate at which the snow is deposited. These data will be used to derive average snow accumulation rates for those sites where annual layer structure is difficult to decipher or where stratigraphic analysis fails altogether.

- Third, the mean crystal size over the full length of a core-crystal growth is a strongly temperature-dependent process, and measurements to be made on U.S. ITASE cores will help bridge a significant gap in the mean annual temperature data between -31º and -50ºC. Data on crystal size can also be used (in conjunction with ice loads based on density profile measurements) to extract mean accumulation rates for those sites where the stratigraphic dating of cores along the traverse routes proves difficult or impossible to accomplish; this is likely to occur at the sites where the temperature is the lowest and snow accumulates the least. (IU-185-O; NSF/OPP 99-80434)

Stable-isotope studies at West Antarctic U.S. ITASE sites.
Eric Steig, University of Washington; James White and Christopher Shuman, Goddard Space Flight Center, National Aeronautics and Space Administration.

As participants in the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), we will perform stable isotope analyses of samples collected during the traverses in West Antarctica. Using instrumental and remote-sensing temperature histories, we will focus on the spatial and temporal distribution of oxygen-18 and deuterium in West Antarctica (where data are particularly sparse) and on the calibration of the isotope/climate relationship on a site-by-site basis.

Our objectives are to

- obtain detailed oxygen-18, deuterium, deuterium-excess, and stratigraphic histories in snowpits at most or all of the U.S. ITASE coring sites;

- provide direct calibration of the isotope/climate relationship at each site through a combination of direct (automatic weather stations) and indirect (passive microwave satellite) temperature measurements;

- obtain isotope profiles covering the past 200 years; and

- use the results to provide climate histories at high temporal and broad spatial resolution across West

Antarctica for the past two centuries.

These climate histories should provide the context to test the relationships that have been proposed among isotopes, moisture source conditions, synoptic scale climatology, and site-specific meteorological parameters. They will also enhance our ability to interpret isotope records from older and deeper antarctic ice cores. (IU-193-O; NSF/OPP 99-04947)

High-resolution radar profiling of the snow and ice stratigraphy beneath the U.S. ITASE traverses, West Antarctic Ice Sheet.
Steven Arcone, U.S. Army Cold Regions Research and Engineering Laboratory.

Ice core measurements provide historical profiles of snow accumulation and chemistry only at the point where the core was drilled, which, along the traverses of the U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE), is every 100 kilometers (km). Subsurface radar, by contrast, provides reflection profiles of continuous horizons, generally related to density and chemistry contrasts; but their continuity strongly suggests that they are isochronal (that is, they demonstrate period regularity). Thus, they can be used to track particular years between core sites and to provide a broader and more meaningful average of year-to-year accumulation rates, given the time versus depth calibrations from the cores.

This project is using high-resolution ground-penetrating, short-pulse radar to track these reflection horizons between core sites. Our main antenna system uses a pulse centered near 400 megahertz (MHz), which provides vertical resolution of about 35 centimeters, and records reflections from a firn depth of about 60 meters (m). During previous years, we tracked some horizons for distances of more than 190 km and found depth variations as great as 22 m over a 5-km stretch. The variations are caused by surface topography, which affects local accumulation rates and ice movement.

We are also using a wide range of frequencies (as high as 10 gigahertz and as low as 100 MHz) to distinguish between conductivity and density as a cause of the reflections. The horizon tracking develops spatially averaged, historical accumulation rates that can be correlated with global positioning system data to find the effects of topography on local accumulation rates. In addition, the radar is also being used for advanced crevasse detection. (IU-311-O; NSF/OPP 98-14589)

Deposition of the HFC degradation product trifluoroacetate in antarctic snow and ice.
Joseph McConnell, Desert Research Institute.

The threat to global ozone posed by the migration of chlorofluorocarbons into the atmosphere, a threat recognized by the 1987 Montreal Protocol and the passage of the 1995 Clean Air Act in the United States, has led to the release into the biosphere of some worrisome substitutes. One of these, trifluoroacetate (TFA), is a highly persistent atmospheric degradation product of the halogenated ethane derivatives.

Since this class of chemicals is now in widespread industrial use, there is growing concern that TFA will accumulate in aquatic ecosystems. Pilot data on TFA deposition at the South Pole indicate a significant increase in the 1990s. However, extant data on the preindustrial (background, or baseline) concentration of TFA in meteoric and surface waters, including antarctic ice, are ambiguous; thus, the impact of anthropogenic TFA on these background concentrations is hard to specify. Ice-core records can provide a useful proxy for background and enable models of anthropogenic TFA deposition to be developed.

Our primary objective is to use ice cores and snow pits at the South Pole to develop a record of TFA deposition

for the past millennium, especially the past 20 years. This preindustrial to present record of TFA in near-surface snow and ice at the South Pole and in West Antarctica will be unique. It should elucidate the origin, transport, and fate of this contaminant over Antarctica and, possibly, the globe. More generally, it enhances the context for assessing potential impacts on antarctic ecosystems from natural and anthropogenic sources by providing vital data on the regional and long-range movement, and the eventual fate, of contaminants. (IU-323-O; NSF/OPP 00-87776)

ANTARCTIC ARTISTS AND WRITERS PROGRAM

Like this geologist working on Mt. Erebus, an active volcano near McMurdo Station, artists and writers also come to Antarctica to learn, so that they may help others understand the significance of this isolated continent and the research done here. *(NSF/USAP photo by Josh Landis)*

The National Science Foundation's Antarctic Artists and Writers Program makes it possible for the humanities (painting, photography, writing, and history) to be part of the U.S. Antarctic Program. Artists and writers work at U.S. stations and camps, often with science groups but sometimes on their own, to create works that portray the region or the activities that take place there.

The Antarctic Artists and Writers Program contributes to NSF's goal of advancing discovery while disseminating results broadly to enhance scientific and technological understanding. The program helps record the Nation's antarctic heritage, responding to White House direction that the U.S. Antarctic Program support the range of U.S. interests in the region. Application procedures and a list of past participants can be found at http://www.nsf.gov/od/opp/aawr.htm.

The next application deadline, for participation in the 2004-2005 austral summer season, will be June 2, 2003.

The selection process for the artists and writers program is comparable to the one for science projects in that a peer-review panel meets at NSF annually to evaluate the applications; this panel's advice heavily influences NSF's selections. The applicants who are chosen receive field support (including air travel from the United States), but no direct award of NSF funds. The program, while intended mainly for U.S. citizens, considers requests from artists and writers in other Antarctic Treaty nations whose applications demonstrate that their works will reach a significant U.S. audience.

The lost men: A book linking modern science and Shackleton's Ross Sea Party.
Kelly B.Tyler.

The Lost Men will be a nonfiction account of the Ross Sea Party of Sir Ernest Shackleton's British Imperial Trans-Antarctic Expedition (1914-1917). Ms. Tyler, a science journalist and historian, will visit research locations and interview investigators to meld modern science with the historical account and thereby provide a deeper context for the expedition. Ms. Tyler produced, wrote, and directed the 2-hour television documentary *Shackleton* for NOVA and was coordinating producer of the IMAX film *Shackleton's Antarctic Adventure*. She will work out of McMurdo Station in November and December 2002. (WO-217-O)

A nonfiction, illustrated children's book about the Weddell seal.
Laurence Pringle and Bob Marstall.

Messrs. Pringle (an author) and Marstall (an illustrator) will collect material for a children's book that describes the life history of the Weddell seal by focusing on a hypothetical individual. They have collaborated on numerous books, one of which, *An Extraordinary Life: The Story of a Monarch Butterfly* (Orchard, 1997), was judged the best children's nonfiction book published in 1997 and won the Orbis Pictus Award for Outstanding Nonfiction for Children in 1998. The team will spend October and November 2002 with NSF-funded investigators studying the Weddell seal in McMurdo Sound. The team also will visit a mummified seal in the McMurdo Dry Valleys. (WO-218-O)

A photographic review of human occupation of the Antarctic.
Joan Myers.

Ms. Myers, a fine-art photographer, will produce photographs that will appear in exhibit and book form. The works will complement those from her earlier trips to South Georgia, the South Orkneys, and the Antarctic Peninsula to illustrate remains from the past, today's research stations, and construction for the future-that is, how we as a species have visited, explored, studied, and lived in Antarctica. Her book *Salt Dreams: Land and Water in Low-Down California*, which was published in 1999 by the University of New Mexico Press, won the Western States Award for nonfiction. She will work out of McMurdo Station for about 3 months beginning in late October 2002. (WO-219-O)

Frigid beauty: Weather in Antarctica.
Thomas E. Svarney and Patricia Barnes-Svarney.

The authors, science writers with backgrounds as professional scientists, will collect material for a science book about antarctic weather and climate for general adult audiences. The book will describe phenomena, effects, origins, and influences of antarctic weather in easy-to-understand terms. In 1999, Simon and Schuster published their *Skies of Fury: Weather Weirdness Around the World*. They will be in the Antarctic for about 3 weeks in late December 2002 and January 2003 to visit weather researchers and forecasters at McMurdo and South Pole Stations. (WO-220-O)

Terra incognita: Anvers Island and surrounding area.
Scott M. Kelley.

Mr. Kelley's recent painting has featured meticulously crafted watercolors of the flotsam and jetsam of the U.S. Atlantic seaboard. He will apply this medium to the Antarctic-painting icebergs, rocks, fishes, and other found objects with the "ironic antiquity" that is characteristic of his Montauk work. One or more exhibitions and a catalog or a small book are expected to result. Mr. Kelley will work at Palmer Station and vicinity in January 2003, joining science teams at their field sites and teaming with WO-223-O, as practicable. (WO-221-O).

To paint in Antarctica.
James D. Woodside.

Mr. Woodside will paint and draw landscapes, seascapes, and wildlife. He will work with oil on canvas or colored pencil and ink on paper, depending on conditions. He chairs the art department of the Walnut Hill School, one of only three residential independent arts high schools in the country, and will exhibit his antarctic paintings at colleges, independent secondary schools, and public schools and will use them when teaching and lecturing. Mr. Woodside will work at Palmer Station and vicinity in January 2003, joining science teams at their field sites and teaming with WO-221-O, as practicable. (WO-223-O)